VOLUME 29 NUMBER 8

NEXT MONTHLY MEETING, NOVEMBER 12, 1907

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PROCEEDINGS

MID-OCTOBER 1907

NEW YORK MEETING, DECEMBER 3-6, 1907

MID-OCTOBER 1907 VOL. 29 No. 3

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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PROCEEDINGS

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 29 MID-OCTOBER 1907 NUMBER 3

THE November Meeting of the Society will take place Tuesday evening, November 12, at 8:15 o'clock.

The subject will be elevators for high office buildings. The principal address, "A High Speed Elevator" by Mr. Charles R. Pratt, published in October Proceedings, treats of the Electric Elevator, which is to be installed in the Singer building and in the Metropolitan Life building.

The discussion will not be limited to this one type of elevator but will be very thoroughly treated by engineers and architects of New York, Philadelphia and Chicago.

THE ANNUAL MEETING

A preliminary program of the papers which will be presented at the Annual Meeting in New York, December 3–6, will be given in November Proceedings. Several of these papers appear in this and the two previous issues. Others will be published in the November and the Mid-November numbers.

It has been the aim to make the session on Foundry Practice especially complete and it is hoped that the papers and discussions will make up to date information available to the Society and foundry men at large.

The Society has also endeavored to meet the need of the times in bringing gas engines and producers before the membership for discussion.

SPECIAL BUSINESS MEETING OF THE A. S. M. E.

Pursuant to call, a special business meeting was held Tuesday evening, October 8, previous to the regular monthly meeting, to ratify the action of the officers in entering into an agreement with the Mechanical Engineers Library Association to merge the two bodies into one, to be known as The American Society of Mechanical Engineers.

Proxies were sent out in the names of Prof. F. R. Hutton or Mr. C. W. Hunt or Mr. Henry R. Towne, and these, together with the ballot vote at the meeting, formally ratified the action which had been taken.

The meeting further prayed that the Supreme Court be petitioned to grant this merger.

On October 15, in the rooms of the Society, will be held a similar meeting of the Fellows of the Mechanical Engineers Library Association, to ratify the action of their officers.

REGULAR MONTHLY MEETING OF THE SOCIETY

Professor John Price Jackson gave the address of the evening which was followed by discussion by the President of the Society for the Promotion of Engineering Education, Prof. Dugald C. Jackson, and by the President of the Society for the Promotion of Industrial Education, Dr. Henry S. Pritchett. Discussion was also offered by Dr. Arthur Hammerschlag, Director Carnegie Institute, Prof. C. F. Park, Director of the Lowell Institute, Mr. C. W. Cross, in charge of the apprentice courses in the New York Central Lines, by the past president, Dr. Frederick W. Taylor, the Secretary, and others. The meeting was considered by all to have been most profitable as dealing with a subject of the greatest moment.

MEETING OF THE COUNCIL OF THE A. S. M. E.

The Council of the Society met on the afternoon of October 8, previous to the regular monthly meeting of the Society, and transacted the usual business, receiving reports from the several standing committees of the Society and approving the appropriations of the Finance Committee for conducting the work for the ensuing year. A large number of new members were approved for ballot.

The Membership Committee is endeavoring to clear up all possible applications previous to the December meeting, but if any applicant

should not qualify, he nevertheless, is especially welcome to attend any of the meetings, particularly the December meeting, which will be of unusual interest.

The Committee on Society History, consisting of the Past-presidents Sweet and Hunt, and Mr. Henry Harrison Suplee, reported that they were ready to publish the early history of the Society, and the Council voted to issue it first as a serial in the Proceedings. This will prove of special value to all the members, many of whom may not be familiar with the early history of the Society. It will also give an opportunity, which the Committee would especially appreciate, to get criticisms and corrections of any facts stated.

Later a memorial volume will be published containing photogravures of the past presidents and views of the several homes of the Society. This will be issued in a very handsome volume.

"COLLEGE AND APPRENTICE TRAINING"

Discussion of "College and Apprentice Training," which was contributed at the meeting held Tuesday evening, October 8, is published in part in this issue. A report of the balance was not available at the time of going to press. It will appear in the November number.

TRANSPORTATION NOTICE

Application has been made to the Railway Association governing this territory for a special rate of a fare and one-third for the round trip to members who attend the December meeting in New York. We have not received definite advice but it is expected that this rate will be obtained.

Further information regarding special rates for the December meeting will be given in the next issue of Proceedings.

OBITUARY

ALBERT F. HALL

Albert F. Hall was born in Somerville, Mass., December 6, 1845. After attending school in Charlestown he entered the first class ever formed at the Massachusetts Institute of Technology. He was the only mechanical engineer in the class which was graduated in 1868. After graduation he entered the employment of the George F. Blake Manufacturing Company, remaining with them forty years, until his death. During this time he invented and designed some of the largest pumps in use in this country, among which are the twenty million gallon triple expansion pumping engines built for the new high service stations of the New York City Water Works.

He was one of the first to advance the idea of heat unit system as the basis to compute the efficiency of the steam engine, and in 1894 he presented before the Society a paper on this subject at the meeting at Montreal. He also contributed many other engineering articles for publication, one of his latest works being on the development of the theory and the practical application of the centrifugal pump.

He made many valuable improvements in the direct acting steam pump, taking out numerous patents. The valve-gear known as the "simplex" was one of his latest inventions. In collaboration with others, he developed the vertical twin air pump and the vertical double-acting suction valveless air pump.

Mr. Hall died at Somerville, Mass., on July 22, 1907.

THE RATIONAL UTILIZATION OF LOW GRADE FUELS

With Special Consideration of the Application of Gas Producers

By F. E. JUNGE, BERLIN, GERMANY
Member Verein Deutscher Ingenieure

GEOLOGICAL RETROSPECTION

It has been estimated by Liebig that the quantity of dry organic matter which is produced by one hectar of farm land, or meadow, or forest, in middle Europe, is approximately the same, namely, 2.5 tons per annum. The output varies according to climatic conditions and geographical location, being larger in the tropics and smaller in the arctics and in the desert regions. Of these organic substances, which consist chiefly of cellulose ($C_6H_{10}O_5$), 40 per cent is carbon, so that, theoretically, the total annual coal production from vegetable materials amounts to 13 000 million tons, which is not quite fifteen times the quantity of coal actually consumed in the world's industries.

2 The assimilation of vegetable matter, or the formation of hydrocarbons, is accompanied by an absorption of carbon dioxide CO_2, from the air, while oxygen O_2, is liberated. If all plants were to accumulate their solar energy in the form of coal our atmosphere would soon be deprived of its CO_2 contents, since about one-fiftieth of the total

To be presented at the New York Meeting (December 1907) of The American Society of Mechanical Engineers, and to form part of Volume 29 of the Transactions.

amount are thus required. So nature has provided that only a fraction of one per cent of the theoretical coal formation is actually reserved in the form of peat, lignite, bituminous coal, anthracite, oil and natural gas for the benefit of mankind. The rest emanates through natural deterioration in the form of gas and reënters the cosmic cycle as carbon dioxide.

3 In contrast to this continuous process of slow combustion stands the exploiting of the world's fuel materials for men's domestic and public utilities and comforts. The kinetic energy of coal which the quiet evolution of centuries has gradually stored up in the sedimentary layers of the earth's crust, is squandered lavishly day by day at an increasing rate of consumption, and hardly 5 per cent of its total calorific value is regained as heat, or light, or power. One thousand million tons of coal, and more, which are thus used in the world's industrial pursuits per annum, return to the atmosphere 1/600th part of its CO_2 contents in the form of exhaust products, and exercise an influence on the temperature conditions of the earth far greater than is usually suspected.

4 The same oxygen that was formed as a by-product of the assimilation of plants millenniums ago is now extracted from the atmosphere in order to support combustion of the carbonized products in boilers, furnaces and gas generators. Its total quantity corresponds approximately to the weight of fossil coal which is accumulated in the sedimentary strata. Atmospheric nitrogen, N, the third element of importance, owing to its chemical inertia, has very likely remained unchanged in the course of time.

ECONOMIC ASPECTS

5 The question whether an exhaustion of what we have termed our irreplaceable fuel resources is a danger for the life and prosperity of future generations, can only be discussed on the basis of theoretical prognostications and speculative arguments. The other question, whether for the benefit of present activities it is wise to economize in the methods of utilization of these resources, cannot be answered but in the affirmative.

6 That individual, or company, or nation will be superior, commercially, to others which can get the most efficient service from the cheapest reliable source of labor, whether manual or mechanical. Never is superior talent engaged for low class work, if there is an alternative available to get adequate help at low prices. Likewise, it is but a matter of political prudence for a nation to exploit the low

grade fuel materials of the country, such as peat, dust coals and refuse, if they can be used for the generation of heat, light and power, instead of wasting anthracite and coke, and to reserve the latter coals for more profitable and important uses in the metallurgical and other industries. An efficient utilization of coal, generally speaking, tends toward the preservation of national values, making a country self supporting and independent on the world's markets. It also aids the prevention of hygienic abuses which, if not amended, are apt prematurely to weaken the earning capacity and the industrial activity of a nation.

7 The conservation of the higher grades and the utilization of the inferior classes of coal has still another aspect to it, namely, that of industrial expansion over territories which were hitherto undeveloped and of no direct value to their owners. All industries depend for their existence on the availability of some form of energy. Nor is water power, which with proper utilization can now be had almost everywhere in the world, always the agent best suited for certain purposes. Thus iron and steel works depend on the continuous supply of high grade fuels such as anthracite, coke and charcoal for the stability of their production. Where these are not available the richest ore reserves are practically worthless. Either the fuel must be transported to the ore or the ore to the fuel.

8 But transportation itself, whether using steam or electricity or gas as motive power, depends largely on the availability of coal to support it, and the cheaper the fuel can be supplied the better for the railroads, for the industries and for all concerned. In those cases, and there are not few, where conditions of service have grown beyond the capacity of steam locomotives, and where electrification of trunk lines connecting great centers of population and industry is becoming an economic necessity, there the large interest on the initial capital outlay for the new equipment must be offset by a saving in fuel cost, which is by far the largest single item of operating expense.

9 So from whatever point of view we look at the problem, it remains a matter of the greatest economic importance to find methods and means for utilizing the enormous stretches of lignite and peat lands, especially those located in the neighborhood of large undeveloped bodies of rich ore which abound in remote districts of the United States and elsewhere, and, either to transform the raw coals into some form of available energy which can be transmitted over long distances at reasonable cost, or to refine the low grade fuels into superior products such as brickets, or coke, or chemicals, that they may serve as a basis for other industries to grow upon and to prosper. The question

which remains to be settled then is not *whether* we should use the inferior classes of coal, but *how* we can use them most efficiently.

10 The effect in a country like the United States of an enormous wealth of natural resources and of an extensive inland market which is protected against foreign competition by high tariff rates is, naturally, to advance the formation of great trust-like combines, to promote large scale production and to favor the standardization of manufacturing methods, which in turn bring large remunerative returns to a few favored individuals, resulting in a rapid accumulation of capital such as is, admittedly, unparalleled in the world.[1] But, at the same time, an ample supply and an ease of disposal of raw materials and finished goods are apt somewhat to diminish the individual and coöperative endeavor of industrial circles toward the attainment of economic excellence in the utilization of inferior products and of such as promise no immediate large returns on the capital invested for their exploitation. On the other hand, scarcity of supply and the necessity to face competition and the urgency to conquer markets at home and abroad, will justify and promote every legitimate effort on the part of manufacturers and consumers, aided by a judicious administration, to procure the best service from the lowest grade of sufficiency.

11 It is evident, therefore, in some smaller European countries, for instance in Germany, where we are supporting over sixty million active people on a territory four-fifths the size of Texas, and where the available fuel resources, especially the high grade ones, are quite inadequate to meet the demand, that the art of utilizing inferior classes of coal, or oil, or refuse must have been cultivated to a higher degree than anywhere else. Thus the very poverty of a country becomes ultimately a source of income to its inhabitants by stimulating the manufacture and the sale of highly efficient apparatus, machinery and processes, and even of skilled talent, to foreign people and markets.

12 Hence it seems reasonable to conclude further—with due consideration in the different countries of the geographical, economical and governmental differences and of the differing industrial policies—that the evolution of that branch of industry with which we are here concerned will take, in the large and scarcely populated countries, a course similar to the development it has taken in those that have to support the largest number of people per square mile of area.

[1] It is interesting to observe that 25 per cent of the business wealth of America is now under corporate control, and that seven eighths of the country's wealth, seven hundred billions, is owned by less than one per cent of the population.

13 With these and other considerations in mind it would seem a very wise policy of President Roosevelt's administration to aim toward preventing the passing of the coal lands of the United States into private ownership and the control of corporations.[1] Of the advantages claimed for the proposed leasing system there are three that bear closely on the subject with which this paper is purported to deal: (1) Government control will prevent waste in the extraction and handling of fuels. (2) It will permit the Government to reserve from general use fuels especially suitable for metallurgical and other special industries. (3) It will enable the Government to protect the public against unreasonable and discriminating charges for fuel supplies."

TECHNICAL CONSIDERATIONS[2]

14 Turning to the technical aspects of the problem, it is opportune first to get a clear idea of the meaning or the signification of the term low grade coal. What does it imply? There is no standard of designation to refer to and none to establish. We cannot graduate the place allotted to each fuel by its relative heat value, nor can we fix its rank in the scale according to the measure of volatiles contained. The transvaluation of by-product values—to adopt an expression of Kant's—that is, the constant change in the appraising of, or in the amount of returns realized from the sale of chemical and other by products which are gained from the various coals, and the constant improvements made in the refining and briquetting of raw materials, make it impossible to define clearly the limits below which a coal becomes inferior.

15 If, owing to their low carbon, high moisture and high ash contents, we speak of lignites and peats as of low grade coals, we are following traditional customs rather than plain facts based on recent developments. Likewise there are conditions under which the smaller screenings or sizes of a high class lean coal may rank equal or lower in monetary value—for instance coke-dust and anthracite-dust which sell at about one-tenth of the price that corresponds to their heat value—than the fuels quoted above. It is only refuse such as culm banks and other waste, which are obtained in very large quantities in coal mining pursuits and which hitherto escaped utilization entirely

[1] It is estimated that already about one half the total area of high grade coal lands in the West is under private control. Only 30 000 000 acres are left for the Administration to take action upon.

[2] For detailed information refer to the author's works on "Gas Power," Hill Publishing Company, New York.

owing to their excessive ash contents (up to 65 per cent), that we can rightly speak of as low grade coals, since both their contents of fixed carbon *and* of volatile hydro-carbons is small.

EFFECT OF ASH, MOISTURE AND VOLATILES

16 Generally speaking, ash and moisture in coal have the disadvantage that they displace valuable combustible matter, thereby reducing the heat density of the fuel, that is, its thermal value per unit volume or space occupied. This inert material must be paid for by the consumer, hence the cost of digging, transporting and handling it must be charged against the coal, thus making it inferior as a fuel to others that possess a higher content of combustibles. Ash and moisture introduce another disadvantage in that both absorb heat. This heat is used for evaporating the water and for bringing the non-combustible matter to the temperature of the fire and maintaining it at that point, so that less heat remains available for useful purposes.

17 In boiler work ash acts not only as a diluent, reducing the heating power of the coal on the grate, but as an actual obstruction to the combustion process, the effect of its presence being thus doubly harmful. When analysing some characteristics of coal as affecting the performance with steam boilers, W. L. Abbot found that when the ash contents of the coal (screenings of various size) had been increased to 40 per cent the coal could still be burnt and would heat the water up to the boiling point, but it would not produce enough heat to make steam. So when heating boilers the useful effect from the fuel drops to zero with 40 per cent of ash, notwithstanding the fact that the other 60 per cent of the composition is pure coal. It is remarkable that, although over half of the composition fed to the fire is fuel, it burns without producing any useful effects.

18 In producer work these drawbacks are not only less felt than with grate firing, but they are actually turned to advantage. Bulk of apparatus and heat radiating surface are factors of secondary importance with producers. They only serve as the central means for making a suitable gas which is used subsequent to its generation and outside of the producer for heating, lighting or power purposes in regulable quantities according to the momentary demand. Heat that may radiate through producer walls or pipings can be used in a convenient manner for preheating either the combustion air or the coal or the water or what other constituents may participate in the gasification process.

19 High ash contents, though increasing the dust contents of the gas and producing clinkers and slag when unduly heated, will promote an even flow of the material through the apparatus when properly treated. Of course, it is preferable to reduce the contents of incombustibles in a coal by washing or briquetting, if there is an alternative to their use as raw fuels at the spot, since this will lessen the amount of handling and poking required. Also, it is obvious that the higher the quantity and the quality of combustibles in a coal and the more uniform its size, the greater will be the capacity and the efficiency of the producer plant, and the more uniform the composition of the gas rendered.

20 But where it is necessary or desired, for reasons of economy, instead of refining and selling the coal, to use it in its original raw shape at the mines at the lowest possible cost and with highest efficiency, then excessive ash contents cannot be regarded as a limiting condition, when producers are employed. In Germany we have been gasifying mine culm, a material containing hardly 25 per cent of combustible matter and up to 65 per cent of ash, in Jahns producers for the last four years with entire success.

21 Moisture, up to a certain percentage which varies with the type of producer used, is not detrimental either. Water, regardless of whether it is supplied with the coal, or with the air, or in the form of steam, acts in one way similarly as the water does in the cooling jacket of a gas engine, namely, as a preventative to excessive temperatures, thereby enabling the working process to be performed without interruption. Excessive temperatures, besides promoting the fusing of the earthy constituents of the charge to slag, are harmful to the materials of the producer wall and grate. With proper adjustment of the steam supply, where steam is added, it is possible to prevent the formation of big lumps of clinker with almost all grades of coal.

22 Water vapor, besides increasing the efficiency of the producer by reducing temperatures all around, when drawn through the incandescent zone or otherwise sufficiently heated, will even serve as a fuel element, enriching the gas by an addition of hydrogen and oxygen. Hydrogen, within certain limitations, is a desirable constituent because it increases greatly the calorific value of the gas and promotes flame propagation. Oxygen will combine with carbon to carbon monoxide and is desirable because it replaces a certain weight of air with its accompanying nitrogen. Nitrogen is an inert diluent, chemically speaking, being of little use to the gas. In the gasification process however nitrogen plays no unimportant part since it acts as an equalising and transmitting medium, absorbing heat in the lower

incandescent zone and yielding it again to the upper layers of coal on its way to the discharge duct. It can be taken, approximately, that two-thirds of the total physical heat are thus conveyed by the nitrogen through the apparatus in up-draft producers.

23 The fact that the moisture in coal absorbs part of the heat of gasification is an advantage in producer work, while it is a drawback in grate firing. Moisture is harmful only when large quantities of it are contained in the gas as produced. This water vapor must be removed from the gas either by dry scrubbing or cooling or compressing, else it will reduce the heat density of the gas and, when the coal contains sulphur, it will produce a corrosive action in washers and pipes, besides having a destructive influence on furnaces and in the steel making process.

24 When dry coal is gasified we obtain temperatures in the gas between 600 and 800 degrees centigrade. When the coal is wet, or when water is added we get temperatures of from 400 to 500 degrees. Hence there is a smaller loss through external cooling of the gas and radiation in the piping. It should be remembered that only a small portion of the total heat that is lost by radiation can be used for regenerative purposes in the producer. Also that it is desirable for all purposes, except when producer and furnace form one unit, to have the gas leave the producer as cool as possible.

25 If we can control the amount of moisture participating in the gasification process, for instance by regulating the admission of steam to a comparatively dry coal, there is an economic maximum for each material which we must not surpass. In one particular case in England it was found that the use of steam over and above that required to saturate the blast at 60 degrees would not lead to higher thermal efficiencies. This will hold true for one kind of fuel only. When using raw fuels of the lignitic and peat class we have to contend with a certain percentage of moisture which cannot be expelled from the air-dried coal except at high temperatures or by briquetting. Therefore so much water must partake in the gasification process, and the question arises: what are its effects, and how can we utilize it most advantageously?

26 The fact is that fuels with some moisture contents and fat coals, which absorb part of the heat of the gas in the distilling zone for driving off the volatile compounds and for splitting them up into stable constituents, are actually superior to lean coals like anthracite and coke as regards efficiency of utilization in gas producers. They also possess this advantage that the gas made contains luminous substances which greatly facilitate the adjustment of gas fired

furnaces. Fat coals are only inferior to lean ones in that they are apt to change their volume and shape in the producer while being heated, therefore requiring more frequent poking. Also, when exposed to the atmosphere they will, during storage, lose about 1.7 per cent of their gas contents in one week, thereby reducing the output of gas and by-products, if the latter are recovered.

27 Attention is called to the interesting experiments of Dr. Wendt made in Germany in which he determined the relative efficiencies of producers working with and without an addition of water. Ordinary boiler coal of high volatile contents was used. When gasifying coals containing much pure carbon a greater difference in efficiency was noted between the dry and the wet process than with others, also a greater difference in the sensible heat of the gas which may be lost through radiation and cooling.

28 With dry gasification of pure carbon there is, theoretically, 70 per cent of the heat value of coal contained in the gas as produced, with wet gasification 85 per cent. In the first case the sensible heat of the gas when leaving the producer is 29 per cent, and in the second case 9 per cent of its calorific value. In practice the heat value of dry producer gas ranges between 900 and 1100 calories (100 and 123 B.t.u. per cu. ft.); that of wet producer gas between 1100 and 1400 calories (123 and 157 B.t.u. per cu. ft.). Higher values are the result of momentary, not of normal conditions in the producer.

29 As for the principal constituents of the gas the analysis shows, approximately, 32 per cent CO for the dry process and 25 per cent for the wet one. The contents of hydrogen is 8 per cent and 14 per cent, and that of nitrogen 60 per cent and 50 per cent respectively. Carbon dioxide ranges up to 3 and 4 per cent, Methan from 1 to 3 per cent. Besides there are traces of acetylen, oxygen, etc. So moisture in producer fuels acts practically as a transformer and distributer of heat, reducing the sensible heat of the gas but increasing its calorific value and heat density, thus making it better fit for outside distribution.

30 While for gas engine work there is a rigid limit to the hydrogen contents of producer gas drawn by premature ignition troubles there is little accurate knowledge available on the question whether high hydrogen contents is harmful when the gas is used for heating regenerative furnaces. Some contend that at temperatures beyond 1500 degrees centigrade dissociation plays no unimportant part and that the quick destruction of furnaces is the result of high hydrogen contents in the gas. Others maintain that it is the water vapor accompanying the hydrogen which is responsible for the damage

wrought, and that a high content of CO is more desirable when a soft reducing flame is required in the furnace.

31 With thorough utilization of the radiating heat of the gas for regenerative purposes up to 90 per cent of the heat value of the coal can be regained in the form of producer gas. But there is a limit to preheating, the same essentially as that drawn to dry gasification, namely, the attainment in the producer of excessive temperatures which its structure and material cannot withstand. When the particular fuel used, or the type of producer employed, or the manner of application of the gas commend the adoption of the dry process or of high internal temperatures, recourse may be had to external water cooling, especially of the parts neighboring on the grate, where clinkers are most apt to stick to the walls and must be removed by the poking bar.

32 Whenever structure and composition of the burnt material afford sufficient support to the charge and uniform access to the air, it is better in up-draft producers to leave the grate out entirely, aspirating air from the circumference toward the center, else the passage for the outflowing material is obstructed by the central pipe and the zone of highest temperatures is shifted near the walls where it is least desired. A comparative test of the two types of producers of the same general dimensions and gasifying the same inferior grade of coal, both having water sealed bottom, the one, No. 1, working with the air supply from the center, the other, No. 2, from the circumference, but both at the same pressure, showed the following results: No. 1 gasified 7 tons of coals in 24 hours leaving 30 per cent of slag, No. 2 gasified between 10 and 12 tons in the same time, leaving only 11 per cent of slag. Unfortunately different fuels offer such widely differing characteristics that it is impossible to pronounce one form or construction as best suited for all coals.

33 American manufacturing methods are noted for their labor saving methods, and typical for their relatively standardized output and their dislike of changing production. In this most modern branch of industry, standardization will fail to effect results such as can be realized in other departments, because when building producers manufacturers must be prepared to meet, by adaptation, separately for each individual case, the wishes and demands of their consumers which, in turn, are dictated by the cheapest fuel available in the particular locality.

34 Automatic charging is an illustration. Laying aside the fact that it increases greatly the dust contents of the gas, there is this misapprehension prevailing among men not familiar with producer

practice, that these devices have the same general effect as automatic feeding has in boiler work. They are supposed to eliminate the employment of manual labor, thereby reducing the cost of the operation of the plant to a minimum. This is only so with coals that do not require treatment subsequent to their feeding to the producer. With the bad caking variety, which abounds in this country, the constant poking required represents a much greater amount of manual work than the charging process proper. So in this case, except perhaps in very large plants, there is no saving realised through automatic charging unless mechanical poking is adopted at the same time. The question is again strictly one of locality, size of plant and kind of fuel used.

35 Though, as we have seen, there are limitations to the efficiency of the conversion of the kinetic coal energy into gas, yet the gasification of coal in producers is superior in almost every respect to grate firing. One reason which has not been mentioned is that in producers complete and smokeless combustion can be attained with a surplus of 20 or 30 per cent of air beyond the amount that is theoretically required, while with grate firing a surplus of air of from 100 to 250 per cent over the theoretical maximum must be expended in order to attain the same result. Hence by far the largest portion of the heat that is generated on the grate is lost on account of the high temperatures at which the products of combustion leave the flues. Therefore, the larger the quantity of products of combustion per unit fuel the less efficient will be the utilization of the combustible material when grate firing is employed, while with producers this deficiency can be more nearly compensated.

36 Enough has been said to establish that high ash and moisture contents in a coal do not preclude its utilization in gas producers, and that the utility of these apparatus ranges far beyond the realm of application of grate, furnace and boiler. Of course, if we come to raw air dried lignites and peats containing over 50 per cent of water, then direct gasification becomes difficult, even when thoroughly preheating air and fuel, and we have either to admix a certain weight of dry coal to the raw fuel or we must briquet it, whereupon the commercial distribution radius of the fuel and its range of application is extended somewhat in proportion to its increased heat density, regularity of form and composition.

EFFECTS OF BY PRODUCT COKE MAKING

37 Taking up another phase of the subject: it is through the logical application of approved methods of the utilization of the

higher grades of coal to the exploiting of the lower species that we have come to abandon the traditional and wasteful practice of appraising the coal according to its heat contents and of utilizing its fuel value only, but now, before destroying coal we analyse it as to its chemical and other values. We are actually doing the same with peat now that progressive industries did long ago with coking coal in by product recovery ovens.

38 The resulting advantages, it is remembered, for the coke making industry were twofold: An increase of from 5 to 10 per cent in the yield of coke, and a return from the sale of by-products varying from 75 cents to $1 per ton of coke made. Yet some countries even to-day are reluctant to change their conservative attitudes toward this only rational process. Take the case of England. If the total quantity of coke made in the United Kingdom for metallurgical purposes is reckoned at 10 000 000 tons, at an average price of $3.30 per ton, the general adoption of by product coke ovens would result in a saving of from $1 750 000 to $3 500 000 derived from the increased yield of coke, while up to $10 000 000 could be derived from the sale of the by-products, provided that the intrinsic value of the latter would remain the same in the future as it is now.

39 In Germany by far the largest quantity of coke is now made in modern ovens since owing to the high development of our chemical industries we possess staple markets at home and abroad for the disposal of the by-products which yield us an annual gain of some $10 000 000. We are just beginning to adopt the same process for the utilization of inferior fuels such as lignite and peat, whenever by product recovery can be carried out on a large enough scale to make it a commercial success. Thus peat from the moorlands of upper Bavaria is subjected to a process of destructive distillation in Ziegler furnaces yielding besides coke and gas a number of valuable by-products. The coke is used for metallurgical purposes and as a substitute for charcoal; the gas for heating, lighting and power purposes. Of the chemical by-products sulphate of ammonia is used as a fertilizer in agricultural pursuits: tar oil, creosote and paraffin serve a variety of useful purposes. So what we do in this case is to split up the coal into a number of separate constituents of which each may serve a different purpose and each may fetch a better price than the original material.

COAL TAR OILS

40 Among the efforts made in Germany to derive all products which are necessary to support the national industry from its own

native resources and without the aid of foreign imports, the activities in the lignite industry are the most noteworthy. It is remarkable how the production and valuation of this fuel which is commonly known under the name of brown coal has increased within the last fifty years.

41 At the beginning of that period, in 1865, lignite held about the same rank as peat holds now. The State of Prussia at that time produced 18.6 million tons of coal, valued at 25 million dollars, and 5 million tons of lignite estimated at 3.5 million dollars. By 1905 we find a production of 113 million tons of coal, worth nearly 250 million dollars, and 44 million tons of lignite worth 25 million dollars. The latter figure refers to the fuel value of lignite, not to the price that may be realized from it including by-products such as paraffin and brown coal tar oils.

42 These oils and others gained from hard coal tar, from caking coal and from bituminous slate are getting more and more valuable since it was demonstrated that they can be used successfully as fuel in Diesel and other oil engines. The annual production of paraffin oils gained from brown coal tar has reached within the last year the figure of 40 000 tons, selling at prices from $19 to $26 per ton. The production of oils gained from hard coal tar, such as creosote oil and anthracene oil, amounted to 84 000 tons within the same period and they were sold for purposes of power generation at the very low price of from $6 to $12 per ton, according to locality. Another interesting product of the coal tar industry is benzol. As a fuel it is fast replacing gasolene and alcohol for automobile and motor purposes, since besides costing only half as much it is more economical and safer in operation.

43 The possibility of gaining from lignitic and other coals and from peat a series of substitute fuels for the ordinary crude oil and petroleum is of great importance even for the future activities of the United States, though this country is apparently very well supplied with raw materials of every kind, especially with oil, marching as it does at the head of all oil producing countries with an imposing output worth almost a hundred million dollars per annum.[1]

[1] In considering the relative values of the mineral and metallic products of the United States, it is found that the fuel materials aggregate about $650 000 000 annually, which is nearly double that of the output of pig iron, and about six times the value of the various precious metals produced. Of this enormous sum, which represents about 40 per cent of the total mineral production of the country, only about one-seventh, or $95 000 000, must be credited to the output of oil, while over one-half is represented by bituminous coal, one-quarter by anthracite, and one-twentieth by natural gas. An interesting fact often lost sight of is that the oil output in the United States has a greater total value than silver and gold together.

44 Yet there stands this incontrovertible fact that oil wells have been tapped so recklessly in the past that the center of production was shifted from Pennsylvania to California, the extreme west of the country, leaving little territory for further exploitation. And there is the other fact that the remaining wells are practically all in the hands of one private corporation, leaving little chance for the Government to establish a control of the kind that would prevent said corporation from selling out such oil immediately and with no regard for future national activities.

45 The enormous extent and the policy of the business which the oil trust has been doing during the last 24 years with the American product can best be realized from the report which the Commissioner of Corporations has recently submitted to the United States Government. Comparing the prices of crude oil with the prices of refined oil and its by-products to ascertain whether the margin between the raw and completed product has been reduced by the improved methods and better organization of the trust, the Commissioner finds that this margin, instead of decreasing, has increased from 6.6 cents per gallon for 1898 and 1899 to 7.7 for 1900 and 1902, and 8.4 cents for 1903 and 1905. Naturally an increase has also taken place in the annual profits of the Standard by reason of this price policy, amounting from 1896 to 1904 to over $27 000 000, while the entire net earnings from 1882 to 1906—based on an investment worth at the time of its original acquisition not more than $75 000 000—were at least $790 000 000, and possibly much more.

46 These figures prove clearly that the beneficial effects of private monopoly power on the national industry and the absence of normal competition are not always what they are claimed to be by their defenders. "The Standard Oil Company," says the report, "gives the public none of the benefits of its superior efficiency, but, on the contrary, charges prices higher than those which would exist in the absence of such a combination." And, we must add, what is worse for America: the rich veins of this colossal country have been emptied of their precious contents—an irrecoverable loss—and the oil, by the manipulations of that company, has been squandered all over the world where it has served and is still serving to support and build up competing industries and skilled talent. In the mean time foreign countries whose natural resources are exploited under the supervision of the government, have preserved their store of oil, small though it may be, and are beginning to lift it now, at a time when its intrinsic value as a raiser of by-products for a variety of industries is being understood, appreciated and duly compensated.

It is only when people lack technical training and industrial forethought or when they have nothing but the immediacy of earnings at heart, that they fail to recognize in the gross exportation of fuel materials from a country a dangerous depletion of its basic resources, working injury to the national welfare.

47 The increasing importance of oil in naval activities is known. An ample and ready supply of it for purposes of national defense is desirable. The event of the utilization of tar oils gained from coal under the control of the Government will prove a more effective restraint to the monopolizing of the oil business by the Standard Oil Company than the appointment of receivers or indictments by the hundred brought by the Federal grand juries against that corporation and the payment of fines exceeding even the thirty million dollar mark.

LIGNITE AND BROWN COAL BRICKETS[1]

48 Another event which is bound to increase largely the value and industrial importance of lignite lands is the transformation of the raw material into brickets. The center of the lignite basin in Germany, which is located on the left banks of the Rhine, has increased its output of raw lignite within thirteen years from 1 016 300 tons to 9 673 100 tons, that is by 851 per cent, and its output of brown coal brickets from 272 580 tons to 2 447 000 tons, that is by 797 per cent. Of this amount 1 810 000 tons are sold in Germany, 291 700 tons are exported and the rest is used in the briquetting industries. Without overestimating the value of statistical figures these data testify well enough to the increasing demand for this class of fuel in European pursuits. The sale of brickets would have been even larger if there had been no car famine.

49 It may be ground for comfort in the United States, where transportation is a serious factor for the briquetting industries to contend with, to know that in a country where the railroads are owned and controlled by the government, being less of a business concern and more of a philanthropic-national institution, such accidents will happen, though with this difference compared to America that they befall large and small dealers alike without discrimination and without secret rebates.

50 The cost of the production of brickets has increased somewhat in proportion to that of ordinary coal, owing to the higher wages paid. For domestic uses they were sold last year at from $2.25 to

[1] For distribution and characteristics of American lignites refer to the regular reports of the United States Geological Survey.

\$2.50 per ton, while for industrial purposes they brought prices from \$1.70 to \$1.80 per ton. The heat value of brown coal brickets ranges from 7700 to 9600 B.t.u. per pound, compared to an average of 4900 B.t.u. per pound of raw lignite containing 45 per cent water. Their heat density is such that up to 3 tons or 60 000 C00 B.t.u. can be stored in a space of 100 cubic feet, hence their commercial distribution range is almost double that of the raw coal.

51 One drawback to the more general application of lignite brickets in industrial pursuits rests with the fact that the smaller sizes which are best suited for producer work are somewhat more expensive to make and yet bring lower prices than the larger sizes, which are now so widely used for domestic firing. Yet they are an ideal producer fuel on account of the regularity of form and composition. An analysis of Bockwitz brickets, which contain about 80 per cent of combustible matter and represent a fair average, shows C 53.3 per cent, H 4.24 per cent, O+N 21.95 per cent, S 1.06 per cent, H_2O 14.65 per cent, ash 5.64 per cent, slag 1.09 per cent, calorific value 4580 calories per kilogram (8240 B.t.u. per lb.) The gas generated from Bockwitz brickets in (Körting) producers shows an average analysis of: CO_2 14.8, O 0.2, H 16.3, CO 11.8, CH_4 2.0, C_3H_6 + C_2H_4 0.4 calorific value 1030 calories per cubic meter (115.4 B.t.u. per cu. ft.) The briquetting tests of the United States Geological Survey show that the Dakota lignites can be treated as successfully as the German brown coal, a fact which will vastly extend the territory which these fuels control.

52 Producers burning brown coal brickets or dry lignite and peat, unless having means like the Pintsch producer for by-passing the volatile gases through the incandescent zone below where they are burnt, employ invariably a second upper incandescent zone. An additional supply of air preheated to about 200 degrees centigrade, (Deutz), serves for the destruction of the tar, or better, of the tar forming hydrocarbons which are decomposed together with the moisture, so that besides the cleanness of the gas there is a double gain in the calorific value of the gas made. No water need be added when the material contains beyond 20 per cent of moisture. No operative difficulties are encountered so long as the water contents of the fuel does not exceed 28 per cent. Instead of clinker or slag a light ash is formed which is easily removed. The actual coal consumption remains in the neighborhood of one pound per horse power hour delivered, costing about one tenth of a cent.

53 In water cooled producers which can work with a high incandescent zone, using high air pressures and allowing the attainment

of high temperatures, raw lignite with up to 50 and more per cent water can be burnt directly without previous treatment. In one iron smelting plant in Germany raw brown coal, containing only 26 per cent carbon, 60 per cent moisture and 30 per cent dust and having a heat value of 2200 calories per kilogram, or 3960 B.t.u. per pound, is gasified in Turk producers, yielding a gas of 1340 calories per cubic meter (150 B.t.u. per cu. ft.)

54 When raw lignite is burnt in producers possessing no provisions for the destruction of tar, and when it is desired to separate out the paraffins from the gas subsequent to its generation in order, on the one hand, to recover the by-products, and on the other, to distribute the gas for heating or power purposes, or both, it is better in large plants, instead of employing any of the well known cleaning apparatus, to press the gas after being cooled down to atmospheric temperature through a motor driven compressor into a double tank whence it is allowed to flow into the distribution main without interruption. The compression and subsequent expansion of the gas will serve very effectively to separate out undesirable constituents, leaving the gas ready for local and other uses in gas engines and furnaces. For the average power plant it is, of course, not advisable to engage in operations entirely distinct from its own special field of work.

THE UTILIZATION OF PEAT

55 If we were to conclude from the manner and extent of the industrial application of peat within the last twenty years to its future possibilities, our prognostications would be both disappointing and wrong. While the use of hard coal within said period has increased in Germany from 60 to 136 million tons, and that of lignite from 15 to 56 million tons, the output of peat has not increased at all, in fact it has diminished. The mistake that has been made is that peat was regarded and utilized as a fuel only and not as a raiser or container of valuable by-products. Peat, since it does not allow of transportation, neither as raw material nor in form of brickets, owing to excessive moisture contents, has no market value. Hence its appraising or valuation depends entirely on the initiative of and on the course of action adopted by the owner of the moorlands. Peat to be rightly used and husbanded must be considered and treated as a material furthering the agricultural possibilities of the soil and not as a means for producing heat, light and power in varied industries, at any cost.

56 Agriculture is the fundamental industry of a country. On its prosperity all other industries are based. Every consideration is subordinate to the idea that the food growing possibilities of the ground must remain in accord with the ever increasing population. The gradual exhaustion of the soil and its territorial diminution caused by the restless expansion of the mechanic industries must be compensated, on the one hand, by utilizing vast stretches of land hitherto void of cultivation; on the other hand, by supplying an ample provision of nitrogenous manure preferably from the country's own native resources.

57 It is a frequent occurrence accompanying ordinary coal mining operations that the soil above the mines will sink and decay, becoming what we call "unland," that is, territory unsuited for agricultural pursuits. When digging peat good farm land is laid bare to the plow ready for immediate cultivation and settlement, thus causing new agricultural possibilities and values to develop. When reclaiming land covered with timber or having stumps upon it, 1 000 000 acres would cost at least $33 000 000 to clear. Peat moreover, contains from 0.75 to 2.85 per cent of nitrogen which can be recovered by proper treatment as ammonium sulphate, giving an excellent fertilizer.

58 Until a short while ago all countries were dependent for their supply of nitrates on the salpeter resources of Chile, which will be exhausted in about forty years. Lately the production of sulphate of ammonia gained in the different countries has replaced the imports of Chile salpeter to a large extent. In 1895 the consumption of imported nitrates in Germany was about 450 000 tons and that of sulphate of ammonia 100 000 tons. Ten years later, in 1905, the former rose to 540 000 tons and the latter to 215 000 tons, or 20 per cent and 100 per cent respectively. Yet the value of the annual imports of nitrogeneous manure which is supplied to that country in form of saltpeter, sulphate of ammonia and guano from abroad amounts still to a total of some $36 000 000, which can be saved by the judicious application of up to date methods. The recovery of the nitrogenous and other by products is the first essential for a rational utilization of peat.

59 Among the technical difficulties which are encountered must be mentioned first the low heat density of peat caused by the high moisture and high ash contents, which vary around 90 and 25 per cent respectively. By the use of kneading and molding machines and air drying, the moisture may be reduced down to about 25 per cent. There are other methods of drying peat, for instance the electrical

process invented by Graf Schwerin and others, that give more economic results than the mechanical process, but they cannot here be discussed in detail.

60 Another technical difficulty of peat utilization is the cumbersome task of dredging and transporting the raw material from the moorlands to the place of usage. This distance increases daily owing to the low heat value and depth of peat bogs. Even when located in the midst of moorlands an industry that would base its operations solely on peat as a *fuel* would soon find in the cost of hauling a limiting condition, also in the fact that this very voluminous material cannot very well be stored so as to be protected against the influence of the weather, and if exposed to the atmosphere it will slack and disintegrate quickly.

61 Attempts to use peat for firing locomotives have failed abroad. The practical question: what does it cost to raise 1000 pounds of steam with peat compared to coal firing, has been decided by Dr. A. Franke, the foremost authority on peat utilization, in favor of coal. So here comes the gas producer as the only economical solution of the problem.

62 Peat with 50 and more per cent water is now gasified in producers with the aid of highly superheated steam (Dr. Caro's patents), yielding, besides sulphate of ammonia, a power gas well suited for use in gas engines. A plant of this kind is operating near Nordgeorgfehn, in Germany, using peat from the Marcard moor-canal, which contains 1.17 per cent of nitrogen. Per ton of dry peat 30 kg. of sulphate of ammonia worth $1.70 and 2500 cubic meters (88 250 cu. ft.) of gas of 146 B.t.u. are gained, which will yield 600 horse power hours in gas engines besides what is used in the process. From the gas driven electric central station current is distributed to the neighboring districts at low prices. Some peat bogs in Ireland contain in their upper, more recent layers, up to 3 per cent of nitrogen. This means that 2 tons of wet peat could yield on an average nearly as much ammonia as 1 ton of coal. To the Mond interests the possibility of using peat instead of slack fuel in producers comes as a very welcome event since it will help to place this process on a commercial footing also in this country.

63 Reference has already been made to the Ziegler process which originated from an attempt to improve the raw peat so as to give a better fuel. Now the idea is to make coke from peat and to utilize the resulting by-products in the most profitable manner. In order to accomplish this, peat with low ash contents and with its moisture expelled down to 18 or 25 per cent as a maximum must be available.

There are two systems of closed ovens or retorts employed, the one yielding a good metallurgical coke and the other one of the semi-variety. The analysis of coke No. 1, of which are gained from 8 to 10 tons per oven within 24 hours, is: C 87.8 per cent, H 2 per cent, N 1.3 per cent, S 0.3 per cent, O 5 per cent, ash 3.2 per cent, calorific value 7800 calories per kg. (14 040 B.t.u. per lb.) Of semi-coke are gained from 12 to 14 tons per oven within 24 hours, and the analysis shows C 73.89 per cent, N 1.49 per cent, S 0.20 per cent, H 3.59 per cent, O 14.52 per cent, ash 2.5 per cent, moisture 3.8 per cent, heat value 6700 calories per kg. (12 060 B.t.u. per lb.) Among the more valuable by-products of the tar are acetate of lime, sulphate of ammonia, methyl alcohol, light and heavy gas oils, which can be used partly as fuel and lighting oils and partly as lubricants, and paraffin and asphaltum. There are several plants of this type working in Germany and elsewhere, the most notable of its kind being the one built on the moorlands of upper Bavaria, at Beuerberg. It is a most interesting illustration of the modern endeavor to secure in the utilization of coals the largest returns from the lowest grade of supply.

MINE CULM, WASH BANKS, ETC.

64 The rational utilization of these materials is of great importance for collieries, where they are available in enormous quantities, and where they have formed hitherto a real nuisance to the works management. Owing to excessive ash contents these banks could not be burnt under boilers, nor could they be dumped back into the mines on account of the danger of causing self ignition of the remaining coal deposits. So they were either stored up in huge piles in the neighborhood of the pit or, where territorial limitations prevented this, they were transported by rail into neighboring dumping grounds, being thus absolutely useless and causing heavy expenditures. There are two possibilities of utilizing these low grade coals: one is to gasify them in Jahns ring producers where their fuel value is utilized, the 25 or 30 per cent combustibles yielding a gas free from tar and well suited for heating, lighting, or power purposes. A plant of this type was built early in 1902 on the von der Heydt coal mines, Saarbrücken, Germany, and has been in active service ever since. The gas generated has an average composition, in per cent of volume, CO_2 12.6, CO 13.1, CH_4 0.9, H 27, O 0.57, heat value (low) 1183 cal. cu.m. (132.5 B.t.u. per cu. ft.) The cost of 1000 B.t.u. in form of producer gas is only 0.005 cent, or one brake horse power hour in gas engines costs 0.05 cent.

65 Another method is that developed by Dr. N. Caro, of Berlin, Germany. It is based on the observation that "wash banks" and other waste contain more nitrogen than that which corresponds to their coal contents. In Westfalian collieries it was found that wash banks, the coal contents of which show on analysis about 1.2 per cent of nitrogen, contain up to 1 per cent of nitrogen, though their total contents of combustible matter is only 25 or 30 per cent. Dr. Caro has succeeded in gasifying this material in producers of the Mond type especially equipped for the purpose, and besides getting a suitable gas he gains about 80 per cent of its total nitrogen contents in the form of sulphate of ammonia. At the same time the sulphur is removed so that the residues of the gasification process can be directly dumped from the producer into the mines without fear of premature ignition. Per ton of wash banks, depending on their value, from 30 to 40 kg. of sulphate of ammonia are gained so that not only the cost of removing the waste coal is recovered but, in addition, a good profit is realized.

COKE BREEZE, DUST COKE, ETC.

66 There are places where fuels of very small size are available in large quantities and at low prices, for instance in gas and coke works, railway stations, etc. Their high ash and dust contents and the small size makes them unfit as boiler fuel, nor are they well suited for transportation. Two ways of utilizing these coals are now open: The one is to burn them in gas producers especially designed for their use; the other is to briquet them, whereupon they become capable of competition with the best grades far and near. Here are some of the points to consider when using dust coals in gas producers: The great resistance offered by the dense fuel material to the passage of air must be overcome by keeping the charge as low as possible and constant and uniform in height, otherwise the air will pass up along the walls, producing clinkers and a bad quality of gas. The coal must be chárged frequently within short intervals and in small quantities, and if containing moisture, it must be preheated by the gas as produced. This exchange of heat will increase the calorific value of the gas at the same time lowering its temperature and that of the process. Producers must be dimensioned larger in proportion to the higher dust content of the material used. The quality of gas rendered is somewhat lower but sufficient for use in gas engines and for heating furnaces, unless very high temperatures are desired.

67 Producers designed in accordance with these principal considerations by Julius Pintsch, of Berlin, and by the Gasgenerator Com-

pany, of Dresden, Germany, have given excellent results with the poorest fuels. A 1000 horse power Pintsch producer plant using coke breeze has been doing uninterrupted service, day and night, since April 1905. The dust coke which settles in the smoke boxes of locomotives, having a composition, in per cent, C 75.2, H 0.4, O + N 1.45, S 0.85, ash 19.2, moisture 2.9, calorific value (low) 6073 calories per kg. (10 930 B.t.u. per lb.) can also be used in these producers and will yield a gas of the following composition, in per cent: CO_2 5.0, CO 26.0, H. 12.0, CH_4 0.2, calorific value (low) 1100 calories per cubic meter (123 B.t.u. per cu. ft.)

68 As an example of how the intrinsic value and the salability of dust fuels can be increased by briquetting, the case of the Gas Works at Riga may be cited. Large piles of dust coke which originated from breaking, handling, storing and transporting ordinary good coke were available. They had been sold hitherto as filling materials for ceilings, fetching a price of 2.5 cents for 100 pounds, while coke in the larger sizes would sell at 30 cents per 100 pounds in that locality. Though the dust coke contained from 75 to 80 per cent of combustibles it was impossible to use it for firing boilers since the fine dust would clog up the flues requiring frequent cleaning and causing heavy expenditures. So a briquetting machine was installed which produced 1000 brickets of 0.4 kg. or 400 kg. (880 pounds) of brickets per hour. An addition of 5 per cent of hard pitch and tar residues as binding material gave sufficient cohesion. The average production in a ten hour day was 4200 kg. (9240 pounds) of brickets having a heat value only 5 per cent lower than coke, the higher ash contents being compensated by the greater heat value of tar and pitch. They make an excellent fuel for boilers and gas producers. By the adoption of superior methods of utilization the returns from this low grade material have been increased from 55 cents realized per ton of coke dust to $3 received per ton of coke brickets.

69 A few words may be added regarding the activities of the United States Geological Survey and the proposed control of coal lands by the Federal Government.[1] In view of the paramount

[1] If a committee of twenty experts chosen by the National Civic Federation after an exhaustive investigation of municipal trading in the United States and Great Britain have come to the conclusion that America, for various well understood reasons, is unripe for municipal ownership of the revenue-producing industries, we must draw the further conclusion that it is ripe for government control of its most needed resources. In Europe the method of partial ownership of public-service corporations has proved very successful.

It has the advantage of effective public control while retaining the stimulus of private interest. The private stockholders can be relied on to prevent political abuses, and the public ownership assures the necessary publicity.

importance of the subject it is a matter of regret for the development of this branch of industry in the United States as well as for science international—noting the inadequate apparatus available at the fuel testing plant at St. Louis and considering the superior progress that has been made in the study of these commodities abroad—that the appropriation for the investigation of fuel problems which has been made by Congress may not be expended for work outside the United States proper. A more liberal endowment of the work of the Geological Survey which would enable that body to proceed with the investigation and dissemination of fuel characteristics and conversion beyond the limits of its present equipment must seem desirable for the future stability of the American industry.

70 The accumulated experience of many European nations that have attempted, from time to time, to operate industrial establishments, bureaus of research and other offices under the supervision of the State, proves conclusively that when a government undertakes to own or to control institutions devoted to the public welfare and fails to supply the means necessary for bringing them up to the highest standard of excellence and for keeping them at that level it will work harm both ways. It discourages those that have devoted their best energies to the work and in the routine of labor find their efforts hampered by insufficient equipments and by pecuniary restrictions, and it destroys the faith of those among the people who do not profit by it in the efficiency of government control as a means for promoting the industrial progress and for furthering the general prosperity of the country.

IN CONCLUSION

71 This subject of which the above gives a brief *exposé* does not allow of narrow technical treatment. It requires breadth of vision and accuracy of knowledge to realize its economic and political bearing on the destiny of nations. One fact however stands out clearly: it is this that, according to the present state of our knowledge, the rational utilization of coals of high volatile contents requires the adoption of gas producers with by-product recovery and the distribution of heat, light and power from gas driven central stations to the neighboring districts, a scheme which is feasible only when operating on a large scale and where staple markets for the disposal of goods lie within the commercial distribution radius of the plant. Fuels of high ash contents, on the other hand, such as mine culm and other waste of low heat value, must be used at the spot in producers

specially equipped for the purpose. Dust coals and similar fuels can either be gasified in producers particularly designed for their use, or they may be transformed into brickets, whereupon competition becomes possible with the best grades of coal for all manner of application. In all cases the employment, in the electric central station, of large gas engines is a logical supplement to the gasification of coals in producers and is the only means, so far available, for attaining maximum industrial economy in the operation of plants of some magnitude.

72 Another fact gratifying for the engineer to see revealed is that industrial progress not only has confirmed but has passed beyond the remarkable prediction of the late Sir William Siemens, which he promulgated as early as 1881, in these words: "I am bold enough to go so far as to say that raw coal should not be used for any purpose whatsoever, and that the first step towards the judicious and economic production of heat is the gas retort or gas producer, in which coal is converted either entirely into gas, or into gas and coke, as is the case at our ordinary gas works."

A FOUNDRY FOR BENCH WORK

A Description of the New Foundry of the Michigan Stove Company

By W. J. KEEP and EMMET DWYER, DETROIT, MICH.

Member and Non-Member, respectively.

On January 8, 1907, nearly the entire works of the Michigan Stove Company were destroyed by fire. Reconstruction was begun at once and by July 1 of the same year, they were entirely completed, having been built on modern lines, substituting alternating electric current and individual motors for belts, shafting and rope drives.

2 On account of poor light, and lack of good ventilation on hot days, it was difficult to get molders to work in the old foundry. The new works, although surrounded by high buildings, are comfortably cool on the hottest days, and the temperature does not rise much during pouring. Fifteen minutes after the heat is off, the foundry is clear.

3 Before deciding on plans for the new works the writers visited several foundries, and found that of the American Stove Company at Bedford, Ohio, best suited to their needs. This plan was accepted with the modifications of an extra row of windows in the roof, and three monitors running crosswise instead of lengthwise.

4 The roof presents some new features as adapted to foundries. A small model was constructed in which an extra row of windows

To be presented at the New York Meeting (December 1907) of The American Society of Mechanical Engineers, and to form part of Volume 29 of the Transactions.

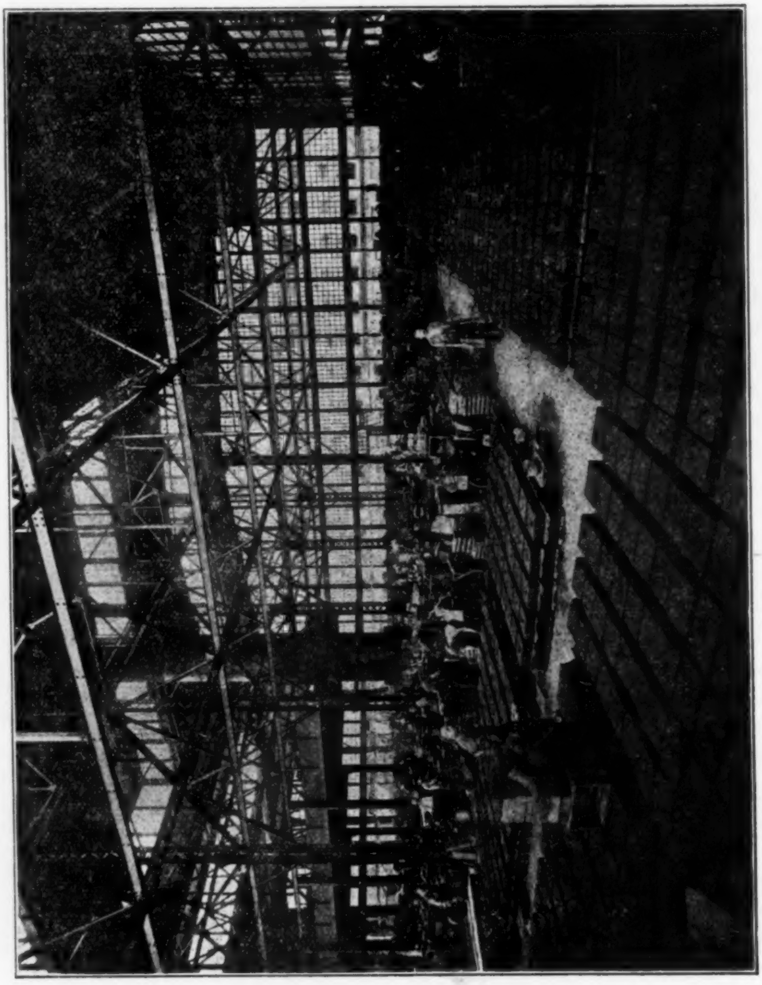

FIG. 1 INTERIOR VIEW OF THE FOUNDRY

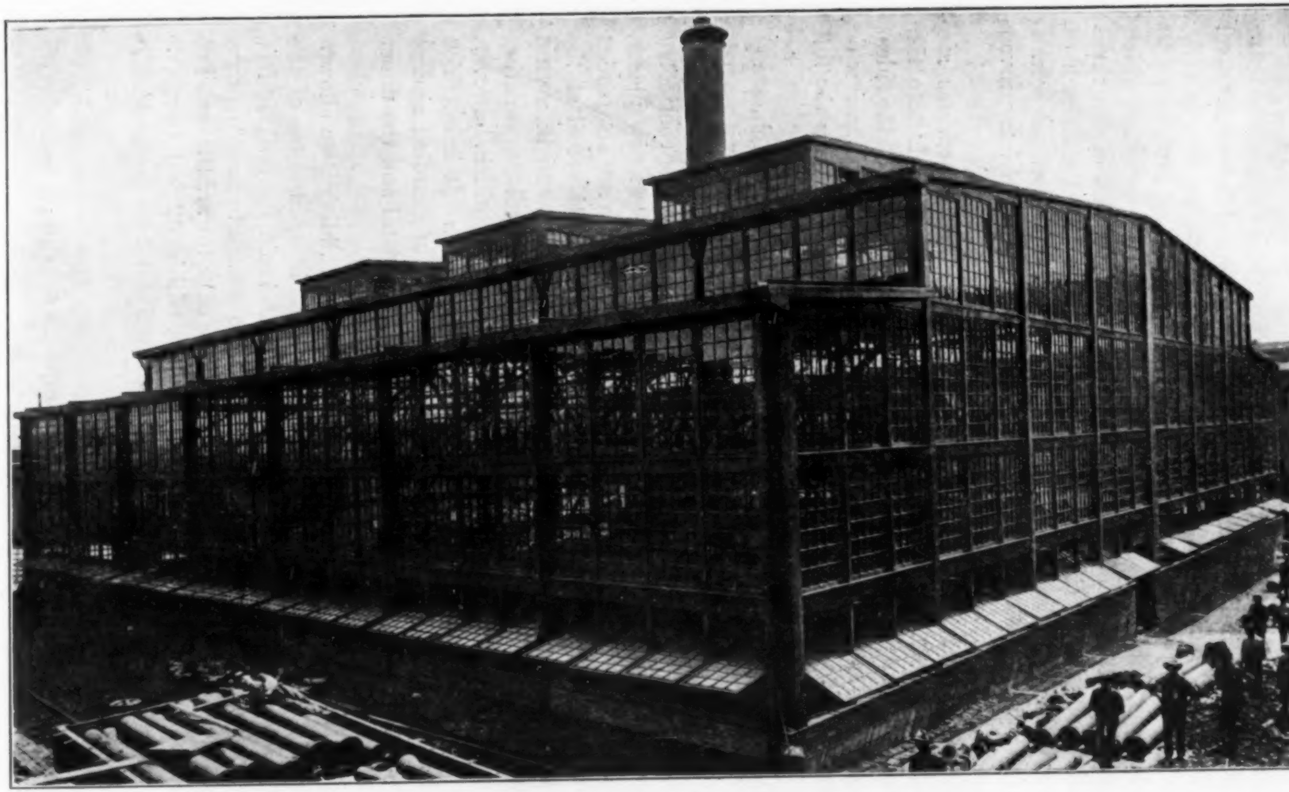

FIG. 2 EXTERIOR VIEW OF THE FOUNDRY

was placed at each side, in the central part of the slope, and the outer edge of each roof section raised to give the usual pitch of a gravel roof.

5 This arrangement allowed the windows in the roof to be 10 feet high, and another row 10 feet high was added on each side, which permitted the use of the ordinary gravel roof, instead of the usual felt roofing with cinders. The disadvantage of the usual form of roofing with the latter covering is that its steep slope does not permit of its being walked upon. The ordinary gravel roof has proved entirely practicable for the purpose.

6 The foundry is 128 feet square; the other dimensions are approximately, 50 feet to the top of the monitors; 40 feet to the highest point in the roof proper, and 30 feet to the roof at the sides. The girders are of 18 foot centers. As an economy in cost, a row of posts was used in the center, instead of having one truss the full length of the span.

7 The foundations are of concrete, the walls, 6 feet high, are of brick 12 inches thick, the balance is constructed of steel, with a roof of 2½ inch matched pine.

8 The building is so nearly fire proof that it is not considered necessary to install sprinklers. There are hydrants at two places, and fire hose with 100 pound water pressure. There are no wooden partitions or wood work other than that covering the steel at the windows—which the architect, being more used to wood than steel construction, insisted upon using to make the building weather proof—and the charging platform, the framework of which, however, is steel with mill construction floor 8 inches thick. It is intended when the wood is perfectly dry (for the purpose of guarding against dry rot) to cover the upper surface with sheet metal and the under surface with some kind of fireproofing.

9 The height of 30 feet at the sides of the building is to allow a deck to be erected at some future time on the line of the top of the first row of windows. The present plan is to begin the deck 10 feet away from the side windows, making it wide enough to accommodate one row of molders, with a gangway at the edge toward the center of the foundry. The under side of the deck will be 12 feet from the foundry floor, and the deck floor about seven feet from the underside of the lowest member of the truss.

10 The floor is of brick, laid in cement. One corner, 18 by 60 feet, is used for a core room, and besides there is ample room for 86 bench-molders.

11 It has not been found necessary to open the monitor windows, it being cool enough when they are closed, but every second window

can be swung open. All of the others are stationary except the bottom row, where each window swings open.

12 Some difficulties were met in removing the cupola from the old location to its present site a distance of 45 feet. It has a 72 inch shell, is 75 feet high, lined to the top, and is estimated to weigh 76 tons. The local movers were asked to submit bids, the lowest of which was $600, and there was no competition for the order even at that price. Finally a house mover agreed to move it for $175. There was no guarantee against accidents in any case.

13 The company furnished $\frac{5}{8}$ inch wire rope for four guy ropes, which were fastened at their outer ends by tackle, and provided the men to manage them.

14 Two timbers were placed under the cupola from front to rear, and one crosswise. These and the cupola were raised with ordinary movers' jack screws until 5 inch wooden rollers and timbers to roll on were placed beneath. A cross timber was fastened by chains on the under timbers, and jack screws between this cross timber and the ends of the timbers and directly under the cupola shoved the cupola along.

15 To insure its being kept plumb, a timber projected from the charging platform door, from which a plumb-bob was suspended by a wire. A plank fastened to the base of the cupola with a nail driven so that its head was directly under the point of the plumb-bob, told which way to raise the blocking. After everything was ready the cupola was moved in ten hours. The mover made a profit of $75, and the entire cost to the company was $225.

16 The foundry will be heated by the forced circulation of hot water, which is to be kept at 157 degrees. The temperature at zero weather is guaranteed to be 45 degrees. The radiation is estimated at 4300 square feet of radiating surface, using $1\frac{1}{2}$ inch pipe.

PATTERNS FOR REPETITION WORK

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A pattern which is run continuously for months, or perhaps years, clearly falls within the limits of this paper as being used for repetition work. And it is just as clear that one which is discarded after a single casting has been made from it should be classed as a pattern for jobbing work.

2 The exact point which marks the division between them depends, in a large measure, upon the size of the foundry and the kind of work it handles, and the two classes frequently merge into each other by imperceptible gradations. Without attempting to fix specific limits, we can use the extreme cases cited above to indicate the lines along which the distinction should be drawn, leaving each pattern user to decide for himself as to the precise position on the scale which he assigns to any given pattern.

3 It is this position which usually determines the expenditure that can be permitted in making the pattern, for it is evident that a cost which would be perfectly legitimate for making say a million castings, might be excessive if only ten thousand were required, and entirely prohibitive for one thousand. On the other hand, the circumstances might be such as to justify a high pattern cost, even for a small number of castings, as for instance, in the case of certain master patterns, further reference to which will be made elsewhere in this article.

To be presented at the New York Meeting (December 1907) of The American Society of Mechanical Engineers and to form part of Volume 29 of the Transactions.

4 Many of the conclusions reached in this paper may be borne in mind to good advantage even in the case of jobbing patterns. But the very nature of the service for which these are intended is such that the designer must leave most of the details to the judgment of the pattern maker; and if the latter fails to catch every important point, it simply means that the molder may have to spend some additional time in producing the desired casting from the pattern furnished him. For whatever use the pattern is intended, the problem resolves itself into a question of distributing the total work in such a way as to attain the greatest economy in the final result.

5 Actual observation of the practical working of different methods of producing patterns has convinced the writer that no pattern which can be legitimately classed as being used for repetition work should ever be made except from a drawing which looks like the pattern, and gives the actual dimensions of the pattern itself. Mention is made of the fact that the drawing should look like the pattern, for the reason that, on small work, the allowances for shrinkage, finish and draft may make the appearance of the pattern quite different from that of the finished piece.

6 In making patterns for repetition work, micrometer calipers, vernier calipers, height gages, etc., are constantly called into requisition, and as it would be both expensive and confusing to attempt to duplicate these in different shrinkage scales, it becomes necessary to work to figures which include the necessary allowances for shrinkage. To the man who is accustomed to big work on which a quarter of an inch is close, and a thirty-second is the very height of refinement, it may seem absurd to use thousandths in measuring patterns. But there are many cases in repetition work where this degree of accuracy is not only desirable but absolutely essential.

7 As an example of the effects of shrinkage and finish, let us assume that we wish to produce the piece shown in the upper part of Fig. 1, the marks *f* indicating finished surfaces.

8 The lower part of Fig. 1 shows the actual pattern dimensions, assuming,

Shrinkage per inch of length,	$S = 0.01$ inch
Allowance for finish,	$F = 0.04$ inch

In this particular case, the various combinations of shrinkage and finish modify the final 4 inch dimensions so as to produce dimensions of 3.96 inches, 4.00 inches, 4.04 inches, 4.08 inches and 4.12 inches on the pattern.

9 In actual practice, the dimensions would not usually be strung out in one continuous line as in Fig. 1, but would probably double

back on themselves to some extent. In addition, the shape of the casting might be such as to make the shrinkage irregular; it might be desirable to allow more finish at certain surfaces than at others, and it might be necessary to make additional allowances for draft.

10 In view of all the factors to be considered, the determination of the pattern dimensions by a process of mental arithmetic may be an excellent athletic exercise for the brain, but it is not a problem which a mechanic should be called upon to solve during working hours.

11 It is also necessary to remember that very few machinists or tool makers have much detailed knowledge of foundry practice, and that the trade of metal pattern making is still comparatively new.

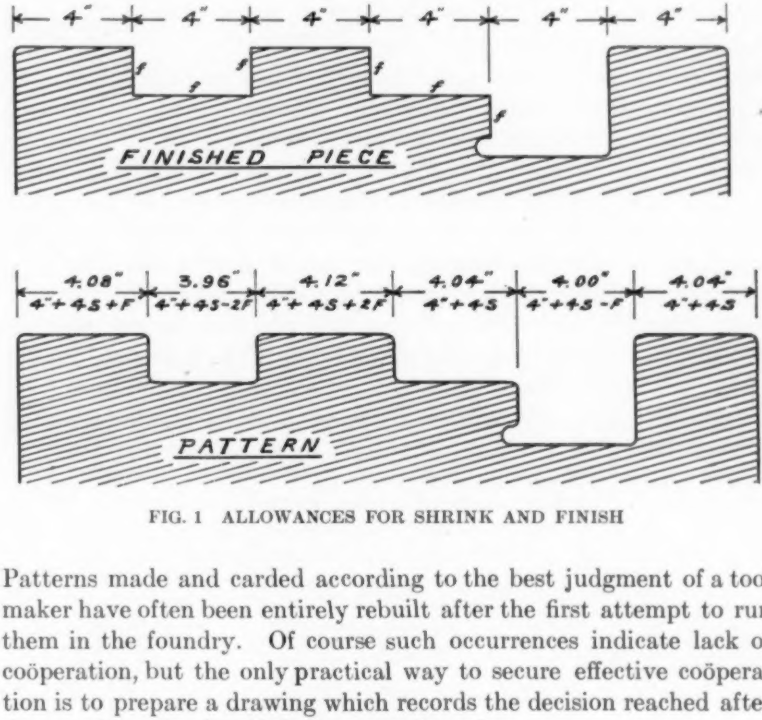


FIG. 1 ALLOWANCES FOR SHRINK AND FINISH

Patterns made and carded according to the best judgment of a tool maker have often been entirely rebuilt after the first attempt to run them in the foundry. Of course such occurrences indicate lack of coöperation, but the only practical way to secure effective coöperation is to prepare a drawing which records the decision reached after due consideration by all the interested parties.

12 There is no doubt but that the best and most economical results are obtained by using men who are skilled in working accurately to drawings, and then supplying them with drawings which they can follow absolutely. Even if it were possible for the workman to carry in his head the various allowances required on a pattern, the lack of

a record covering them would lead to endless trouble and confusion. If a pattern has to be duplicated or replaced, the worn one must either be copied as closely as possible, or the workman, who may or may not be the author of the original pattern, must introduce a new set of allowances. And while it sounds simple to tell a man to "make another just like this," we all know how the little errors accumulate until the final result is startlingly different from the original. It is said that a Chinaman can and will copy a model with absolute fidelity, but no one has ever had the hardihood to make a like assertion in regard to a workman of any other nationality.

13 For computing shrinkages, the drawing room should be furnished with a table giving the shrinkage per inch (in hundredths or thousandths of an inch) for each of the materials commonly used. This shrinkage, multiplied by the length in inches of any part of the casting, gives the allowance in inches direct. It may seem superfluous to explain this apparently self evident procedure, but the author has seen cases in which the shrinkage was expressed in fractions of an inch per foot of length and in which each dimension was carefully translated into decimals of a foot before multiplying by the constant.

14 It will frequently happen that there are certain parts of a casting where a high degree of accuracy is not necessary, and a very little time spent by the drawing room in determining and indicating these points will be amply repaid by the saving in making the patterns. The required degree of accuracy can best be indicated by means of the number of decimal places in the figure giving the dimension. In using this method there must be an understanding between the drawing room and pattern maker that the permissible error is never greater than one in the last decimal place. For instance,

1.127 indicates a permissible error of 0.001 inch ±
1.120 indicates a permissible error of 0.001 inch ±
1.12 indicates a permissible error of 0.01 inch ±
1.10 indicates a permissible error of 0.01 inch ±

15 Reference to the Fig. 2 to 14, illustrating the various methods of carding, and to Fig. 15 to 25 illustrating the location of the parting line, will show that many different arrangements for draft are possible, although only one may be desirable. The pattern drawing should therefore show where the parting comes, and should indicate the amount of draft to be allowed at different points. The allowances for draft are discussed in detail under a separate heading.

16 A carding drawing should be prepared in conjunction with the drawing of the pattern itself. These must be carried along to-

gether, as a change in one will usually affect the other. The carding drawing should show clearly the arrangement of the runner, the enlarged portion of the runner where the sprue is to be cut, the location and size of the gates, the points at which they join the patterns, the arrangement of the patterns, the location and size of risers or shrink balls, if used, and the connections, if any, which may be needed in addition to the gates for supporting the patterns. It may really be looked upon as an assembly drawing, and will usually require only a few dimensions.

17 To avoid the confusion which might arise if carding drawings sometimes show the drag side and sometimes the cope side, it is well to adopt the rule of showing all cardings as they would appear when looking at the drag side. In the case of an "open" carding, this rule causes the pattern to be shown as it appears when looking down on it as it lies on its mold board.

18 Turning now from the general requirements, we may, for convenience, group under the following headings those details which involve a consideration of the peculiarities of each individual case:

A The number of patterns to be grouped in one card and the size of the flask.

B The method of carding, whether mounted on a "plate" or as a "split" pattern, or "open" for use with a mold board, etc.

C Location of the parting line.

D Allowances for draft.

E Arrangement of the gates, runners, risers and supporting connections.

F The material of the pattern, and of the runner, plate, mold board, etc.

G The points on the pattern at which special accuracy is required.

H The amount of work to be expended on the pattern.

19 These in turn depend on the given conditions which may be tabulated as follows:

a The size and shape of the casting.

b The special requirements, if any, which may call for placing the pattern in a certain position or for providing risers, shrink balls, etc., in order to secure sound castings.

c The machining operations to be performed on the casting.

d The locating points for these operations.

e The points at which fillets and rounds are required.

f The degree of accuracy needed at unmachined portions and points, if any, where special accuracy is required.

g The rate at which the castings are to be produced.

h The probable total number required.

i The probable length of the intervals during which the pattern is out of use, and the conditions under which it is stored during these intervals.

20 Having determined the considerations affecting the design and construction, we may consider them in detail.

THE NUMBER OF PATTERNS TO BE GROUPED IN ONE CARD, AND THE SIZE OF THE FLASK

21 For snap flask work it is usually necessary to allow a wall of sand about one inch thick outside of the extreme points of the patterns. If the card consists of a number of small patterns, the walls of sand between them tie into the outer wall and help to support it. Under these conditions no further support is necessary for castings extending say ½ inch or less above or below the parting line. If the castings are deeper, or if there is a considerable length of outer wall which is not supported by other walls tying into it, a band may have to be provided, but the one inch dimension may still be maintained. In most cases the work of handling the band is less than the work of handling the increased amount of sand required by a larger mold. Even if iron flasks are used, the one inch dimension should generally be adhered to, as there is apt to be trouble in ramming, and danger of the flask acting as a chill if the outer wall of sand is reduced much below that figure.

22 Unfortunately the manufacturers of foundry supplies seem to have made no attempt whatever to select certain sizes of flasks which can be looked upon as standard, and therefore given the preference whenever circumstances permit. Their catalogues usually state that they will make any size of flask desired, but this does not help the man who is endeavoring to standardize his equipment.

23 Special sizes can never be entirely avoided, but the author recommends the general adoption of two sizes which have proved very convenient for small snap flask work. The smaller of these, 9 by 16 inches, inside measurement, is the best all round flask for work within its range. The larger one, 10 by 18 inches, inside measurement, is nearly as convenient, and there is no serious objection to its use, provided it permits of a more advantageous grouping for a given pattern. There is, however, a limit beyond which the increased

weight of each mold more than offsets the advantage secured by the reduction in the number of molds. Experience shows that the output with a mold 9 by 16 inches is just about equal to the output with a mold 10 by 18 inches holding one third more castings. Whether or not the larger flask will increase the capacity more or less than this amount can be determined only by laying out the possible groupings for each size.

24 Whenever there is a choice between any two sizes and their outputs are practically equal, the preference naturally rests with the smaller one as involving the smaller expense for patterns, flasks, etc.

25 In fixing the length and width of a flask, the designer has usually some latitude as he can vary the grouping of his patterns, but the depths of the drag and cope áre less under his control. As the sand in the drag is never called upon to support its own weight, the depth of the drag need never be greater than is necessary to provide sufficient sand (say $1\frac{1}{2}$ inches after ramming or squeezing) below the deepest portion of the pattern. The depth of the cope must be sufficient to give a corresponding amount of sand above the pattern, and it must also be sufficient to make sure that the sand will support its own weight when the cope is lifted. The depth of the cope will sometimes be fixed by one and sometimes by the other of these requirements.

26 If the ramming is done by hand, the mold is struck off flush with the flask, and the depth of the latter corresponds with the desired depth of the mold. If the mold is squeezed by power, the flask must be deeper than the desired depth of the mold by an amount equal to the squeeze. The squeeze may be figured as about four tenths of the original average depth of loosely packed sand.

27 If the pattern is mounted in a frame, the depth of the drag half of the flask must be further corrected by deducting an amount equal to the thickness of the frame. The frame should always be considered as belonging to the drag half of the flask.

28 The following table gives the minimum depth of flask which experience has shown to be permissible for a cope, squeezed by power, in order that the sand may support its own weight.

TABLE 1 MINIMUM DEPTH OF FLASK

SIZE OF FLASK IN INSIDE MEASUREMENTS	MINIMUM DEPTH OF FLASK GIVING A COPE THAT CAN BE LIFTED	APPROXIMATE DEPTH OF COPE HALF OF MOLD
9 by 16 inches	3 inches	$1\frac{7}{8}$ inches
10 by 18 inches	$3\frac{1}{4}$ inches	2 inches
$12\frac{1}{2}$ by $17\frac{1}{2}$ inches	$3\frac{1}{2}$ inches	$2\frac{1}{8}$ inches
$13\frac{1}{2}$ by $15\frac{1}{2}$ inches	$3\frac{3}{4}$ inches	$2\frac{1}{4}$ inches
14 by 23 inches	4 inches	$2\frac{3}{8}$ inches

29 If the conditions require a deep flask, or one which is larger than either of the two sizes mentioned, care should be taken whenever possible to avoid molds beyond the capacity of a single operator.

30 For snap flask work the limits for a one-man mold are about as follows:

- A Width 12 inches inside of flask. A greater width makes the mold liable to tip toward or from the operator.
- B Length 24 inches inside of flask. A greater length requires an excessive spread of the arms.
- C Weight 85 pounds corresponding roughly, for flasks of average depth, to an internal flask area of 250 square inches.

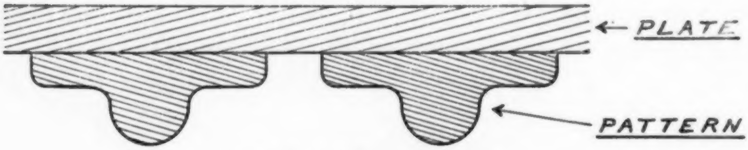


FIG. 2 "PLATE" PATTERN

31 Care should be exercised to avoid molds which are square or nearly square, as they are liable to tip, even if the width is less than the 12 inches specified above. The best shape is obtained when the width is from $\frac{5}{10}$ to $\frac{6}{10}$ of the length.

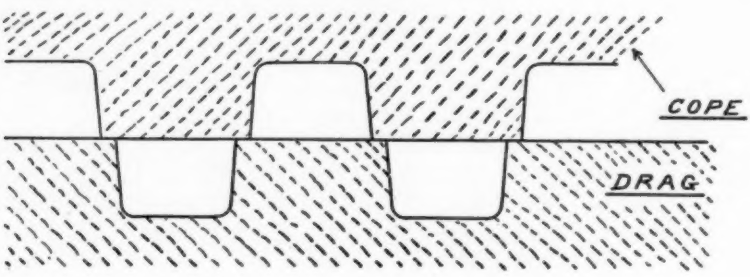


FIG. 3 CASTINGS STAGGERED IN DRAG AND COPE

32 When carrying a mold supported by a solid flask the operator can rest it against his body, whereas a mold from which the flask has been removed must be swung free from all danger of contact. For this reason solid flasks may be somewhat larger than snap flasks in spite of the fact that the flask itself has to be handled in addition to the mold. The permissible increase may be taken at about 10 per cent in length, 30 per cent in width, and 50 per cent in weight.

33 Although output is an important consideration, we must not lose sight of the fact that it is not the sole determining factor in selecting a flask size. If the required rate of production is low and the probable total requirements small, it may pay better to mount a few patterns on a small card in preference to carding even a considerably increased number for a slightly larger flask. Further reference to this will be made under heading "The amount of work to be expended on the pattern."

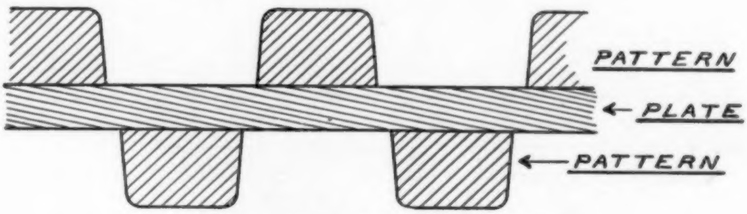


FIG. 4 "STAGGERED PLATE" PATTERN

34 Every possible care should be exercised to limit the number of different sizes of flasks. A record should be kept of all existing sizes, and no new size should be created unless it is perfectly certain that none of the old ones are suitable.

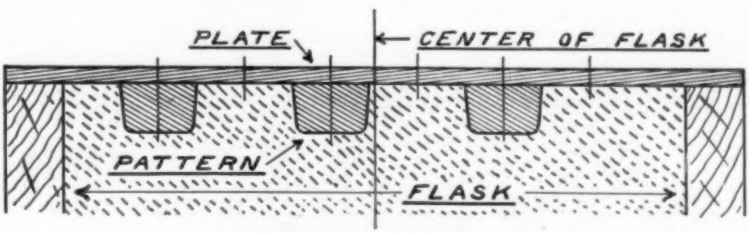


FIG. 5 "REVERSIBLE PLATE" PATTERN

THE METHOD OF CARDING

35 It will nearly always be a safe rule to use a plate whenever the pattern permits. It gives the most durable construction, and except in special cases, such as those shown in Fig. 5 and 11, it permits of making both halves of the mold at once. The simplest case arises when one side of the pattern is flat, permitting it to be mounted as shown in Fig. 2.

36 If, instead of being shallow, the pattern is deep, a considerable space must be left between adjoining patterns to give a sufficient wall of sand. In such a case a saving can be effected by putting the

patterns alternately above and below the parting line as in Fig. 3. This can be arranged in two ways; by actually mounting patterns on both sides of the plate, as in Fig. 4, or by making only half the number of patterns and mounting them on one side as shown in Fig. 5.

37 It is evident that if the first half mold made is used as the drag and the next one turned over and placed on it as the cope, the desired staggering will be obtained. This style of plate is sometimes known as a "reversible plate," although, strictly speaking, it is the mold and not the plate that is reversible.

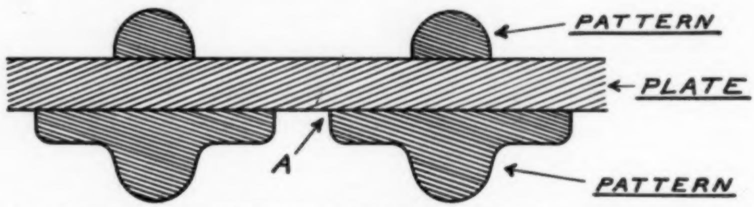


FIG. 6 "PLATE" PATTERN WITH PORTIONS OF PATTERN ON EACH SIDE OF PLATE

38 The first method gives the greater output, as both halves of the mold may be made at once. It is to be preferred for shallow patterns of simple form, as it obviates the necessity for special accuracy in locating the patterns and keeping flask pins true. If the pattern is complicated, a decided saving in pattern cost can be effected by using the second method. If the pattern involves a deep draw, the second method is again to be preferred, as it requires only the

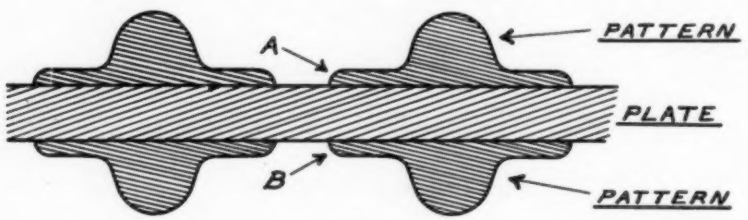


FIG. 7
"Plate" Pattern Calling for Accurate Matching of Drag and Cope

lifting of the pattern from the sand, and not the lifting of the cope off of the pattern. The "reversible" method has the disadvantage which may in some cases prove serious, of producing half the castings under one set of gating and cooling conditions and half under another set. This is referred to in further detail.

39 Careful work to make the two sides of the plate match, and to keep the flask pins true is necessary if portions of the pattern

have to be mounted on opposite sides of the plate. If a square corner is permissible at A, they may be mounted as in Fig. 6. If a round corner is required at both A and B, they must be mounted as in Fig. 7. The staggered arrangement can also be used for patterns extending on both sides of the parting line as in Fig. 8.

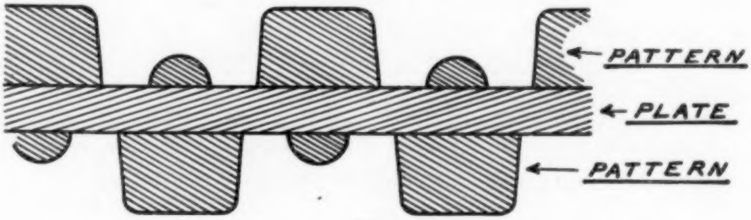


FIG. 8
"Staggered Plate" Pattern with Portions of Pattern on Each Side of Plate

40 In order that the two halves of the mold may meet properly the vertical distance between the upper and lower faces of the plate must be constant throughout, excepting at certain points where an excess thickness is purposely provided, as referred to later. This condition can be easily met if the parting surface is a plane, but

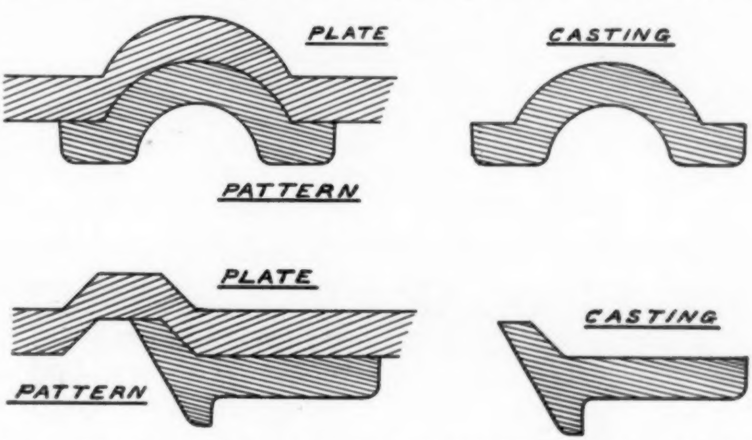


FIG. 9 "PLATE" PATTERNS IN WHICH THE PARTING SURFACES ARE NOT PLANE

prohibits the use of a plate if this surface assumes a complicated shape. If the surface can be given some simple geometrical form which can be easily machined, a plate can often be used to good advantage even if the parting is not in a single plane. Several cases of this kind are illustrated in Fig. 9.

41 In making such plates, the best results will be obtained if a little extra thickness is given to the plate at any points where an exact fit of the mold is not required. For example in the first of the patterns shown in Fig. 9, the different sections through the molds should appear as shown in Fig. 10.

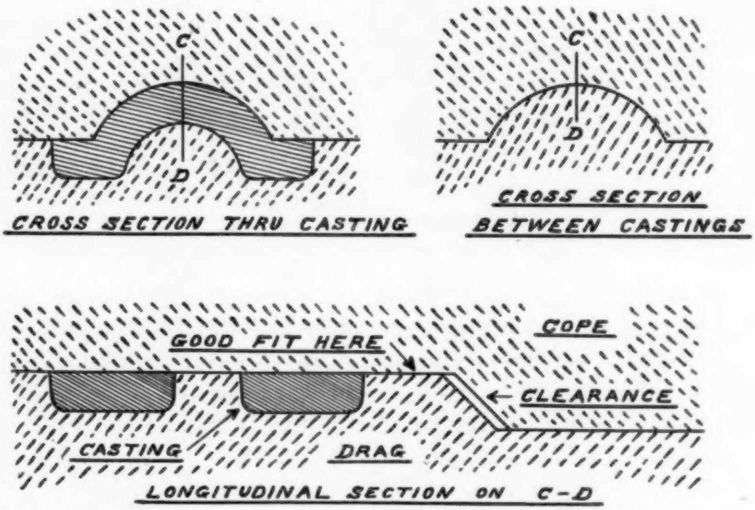


FIG. 10 CLEARANCE AT UNIMPORTANT PORTIONS OF PARTING SURFACE

42 The "split" pattern is really a modification of the patterns shown in Fig. 6, 7 and 8, which is used if the draw is so deep that the cope can not well be lifted off of the pattern. In such a case the pattern is split, each half being separately mounted as in Fig. 11.

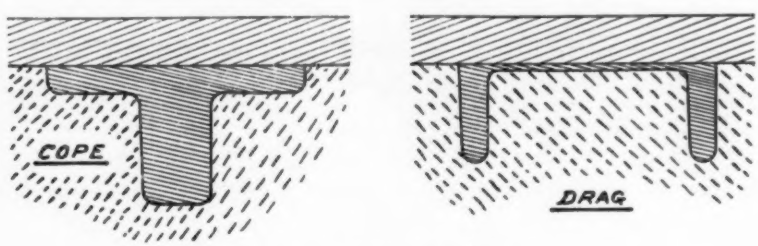


FIG. 11 "SPLIT" PATTERN

The pattern is lifted from the drag and also from the cope, and the latter is turned over and set on the drag, making the completed mold appear as in Fig. 12. If used with a stripping plate the principle is

the same, only the patterns are reversed and drawn downward through the plate, instead of being lifted up. If the casting happens to be symmetrical about the parting line, a single pattern can be used for both the drag and cope.

43 If the parting surface is too irregular for a plate the ordinary pattern connected to a runner and provided with additional supports, if necessary, must be used, so as to make an "open" carding. As this construction gives no backing to the pattern, a separate support must be provided in the form of a mold board. The use of the mold board makes it impossible to ram up both halves of the pattern at once. If power squeezers are used with this style of pattern, special care must be taken to give the drag a heavy squeeze and the cope

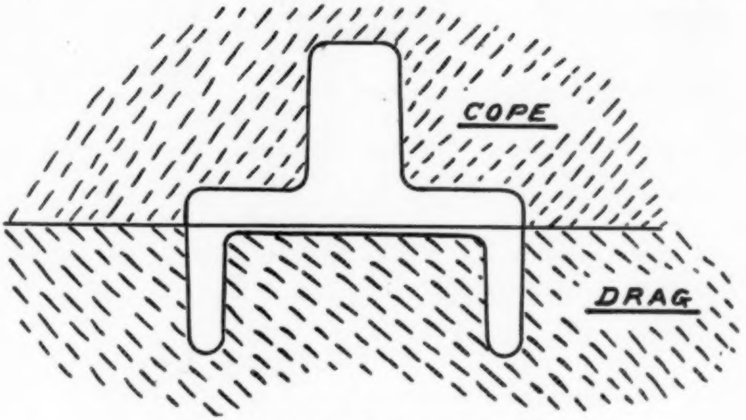


FIG. 12 MOLD MADE FROM "SPLIT" PATTERN

a light one. If this precaution is not observed the pattern will be sprung, and pressed still further into the drag half, when the cope is squeezed. When ramming by hand there is less danger of springing as the support afforded by the drag has to resist only the localized blow of the rammer instead of a pressure exerted simultaneously over the entire parting surface.

44 If the molds are squeezed by power, it is desirable to put cleats under the mold board so that the total height will be such as to keep the idle portion of the stroke as small as possible at all times.

From Fig. 13

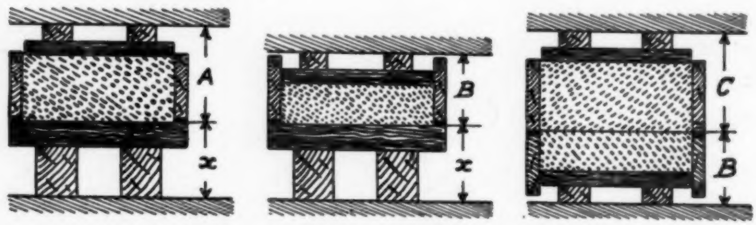
$$A + x = B + C$$

it follows that

$$\text{Desired height of mold board, } x = B + C - A$$
$$= C - (A - B)$$

where C is the combined height of cope and squeezing board before squeezing, and $A - B$ is the amount of squeeze in the drag.

45 Locating the cleats so as to reduce the deflection of the mold board to a minimum is a matter which deserves attention, particularly in the case of long flasks. It may be assumed that the pressure exerted on the mold board through the sand is practically uniform at all points, and the mold board may therefore be treated as a girder, resting on two supports and uniformly loaded as shown in Fig. 14.



Ready to squeeze drag After squeezing drag Ready to squeeze cope

FIG. 13 HEIGHT OF MOLD BOARD

46 For a pressure of P pounds per inch of length, the deflections may be represented as follows:

$$\text{Deflection at ends of mold} = \frac{P\left(\frac{L-D}{2} - W\right)}{8} \frac{\left(\frac{L-D}{2} - W\right)^3}{E\,I}$$

$$\text{Deflection at center of mold} = \frac{P\ D}{384} \ \frac{D^3}{E\ I}$$

Placing these equal to each other, and solving we get

$$D = \frac{\sqrt[4]{3}}{\sqrt[4]{3} + 1}\ (L - 2\ W)$$

$$D = 0.568 \quad (L - 2\ W)$$

47 The cleats on the bottom boards and squeezing boards should be centered with the cleats on the mold boards. The thickness of the squeezing board and of the bottom board, including the cleats in both cases, must be greater than the distance traveled in squeezing. The middle view in Fig. 13 will make this clear.

LOCATION OF THE PARTING LINE

48 The location of the parting line, both with reference to the pattern itself, and with reference to the edges of the flask, is highly important, and the judgment used in its selection may make the whole difference between success and failure in producing the molds. In locating it we should be governed by these rules:

- A Avoid steep inclines in the abutting surfaces of the drag and cope. Always keep these surfaces as nearly square to the line of lift as possible.
- B Avoid unsupported projections of sand, particularly in the cope. Avoid hanging pockets of sand in the cope.

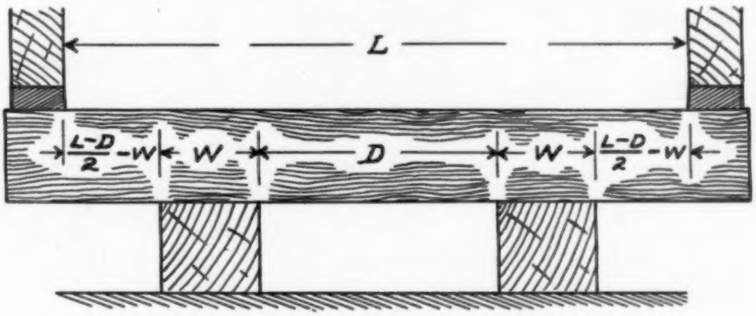


FIG. 14 SPACING OF CLEATS

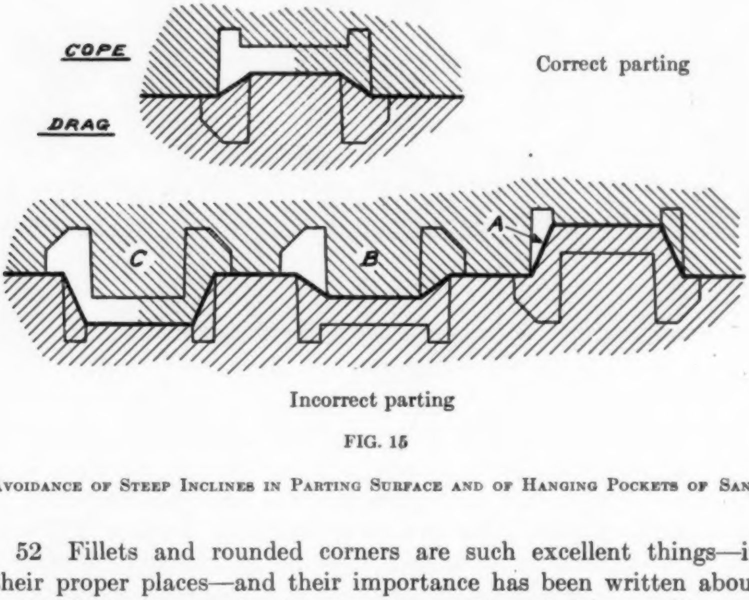
- C Make the draw in lifting the cope as small as possible.
- D Where a draw in the cope is unavoidable, endeavor to keep it up within the flask so that the latter will support it.
- E When practicable, avoid a parting surface which intersects a face of the casting. Give the preference to a parting which forms a continuation of a face even if a rounded corner has to be sacrificed.
- F If a mold board is used, avoid exposed joints between it and the pattern.

49 Following these rules the first of the partings shown in Fig. 15 to 19 inclusive are the ones to be preferred in each case. Partings similar to those shown in Fig. 20 to 24 inclusive should be used only if necessary, and of the two partings shown in Fig. 25 the first is to be preferred.

50 Fig. 15 illustrates the avoidance of the steep incline at *A* and of the hanging pockets of sand at *B* and *C*. Fig. 16 illustrates the

avoidance of the unsupported projections of sand at *D* and of the hanging pocket of sand at *E* and *F*. Fig. 17 and 18 illustrate again the avoidance of hanging pockets of sand at *G*, *H*, *J* and *K*, and Fig. 15 to 19 inclusive illustrate the features of keeping the draw in the cope as small as possible, and of keeping it up inside of the flask.

51 It is interesting to note that the application of these rules results, in different cases, in locating the casting in each of the three possible positions in the mold, namely: entirely within the cope, as in Fig. 17; partially in the cope and partially in the drag as in Fig. 18; and entirely in the drag as in Fig. 19.



Incorrect parting

FIG. 15

AVOIDANCE OF STEEP INCLINES IN PARTING SURFACE AND OF HANGING POCKETS OF SAND

52 Fillets and rounded corners are such excellent things—in their proper places—and their importance has been written about and talked of so much, that we are sometimes led into calling for them in places where they are of no help to the casting, and really become very objectionable on the pattern.

53 For instance in the very simple pattern shown in Fig. 2. If it were absolutely necessary to round all the corners it would have to be mounted as shown in Fig. 20, adding extra expense to the making of the pattern, and making it necessary to exercise constant vigilance to keep the flask pins true.

54 If it were permissible for the corners *B* and *C* of Fig. 20 and 21 to be square, the pattern might be mounted as shown in Fig. 21. This would still permit of a round at *A*. If a fillet were required at

C of Fig. 21, it would run out to a feather edge at the upper surface of the plate, and if a smooth and true surface were required at that point of the casting, the pattern would have to be set into the plate

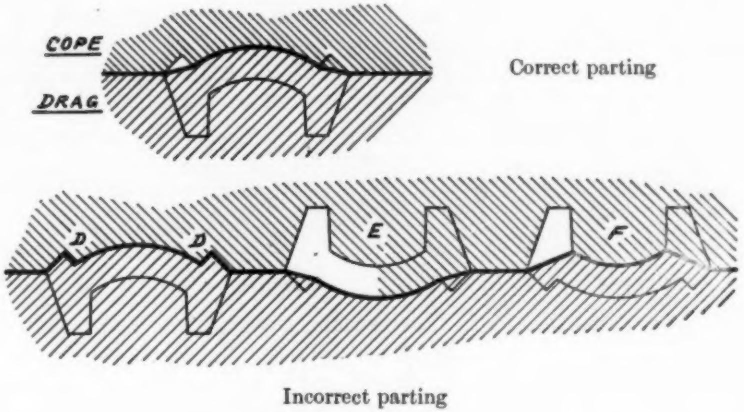


FIG. 16
AVOIDANCE OF UNSUPPORTED PROJECTIONS OF SAND AND OF HANGING POCKETS OF SAND

as in Fig. 22. The objection to this fillet applies only to "plate" patterns and not to "open" cardings. If carded "open," the mold and pattern would appear as in Fig. 23. The objection to the double rounded corners, however, holds for the "open" carding as well as

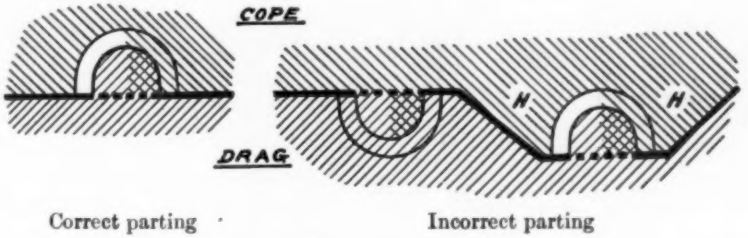


FIG. 17 CASTING IN COPE

for the plate, as the cope, instead of being flat, would have to be brought down as shown in Fig. 24.

55 Whenever a rounded corner involves the shifting of the parting line from its best position, an effort should always be made to modify the design so as to permit of a square corner at that point. If the trouble is feared from the chilling of the corner it is well to remember

that in hand molding this chilling is more frequently due to wetting the mold than to the actual sharpness of the corner. In machine molding, using well made patterns with ample draft, there should be no occasion whatever for wetting the edges of the mold.

56 In avoiding objectionable projections or hanging pockets of sand, it will be of assistance to bear in mind that the mold board corresponds exactly to the cope, and that all irregularities in one

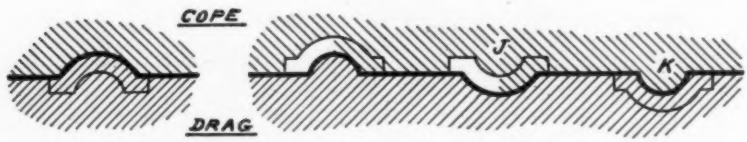


FIG. 18 CASTING PARTIALLY IN DRAG AND PARTIALLY IN COPE

will be reproduced in the other. It is therefore always desirable to keep the mold board as free from such irregularities as may be consistent with the other requirements which have to be met.

57 In the case of the pattern shown in Fig. 25, it makes little difference, as regards the draw, which side is put in the cope. But of the two positions shown the first is to be preferred, as it avoids the exposed joint at *D*. Such a joint requires careful fitting when

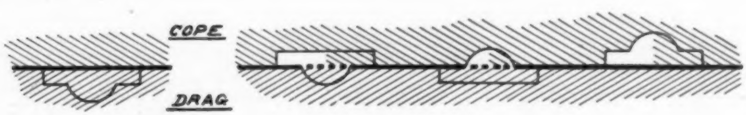


FIG. 19 CASTING IN DRAG

the mold board is made, and frequent repairs are necessary to maintain its accuracy. By placing the pattern in the first position it covers the recess in the mold board entirely. In this case the recess merely becomes a clearance opening, and no fit is necessary, except perhaps at the bottom, in order to support the pattern and to prevent it from springing. The first position has the further advantage of requiring the removal of less material from the board. The carving of a mold board is a tedious and expensive hand operation at the best, and every method of reducing this expense is well worth considering.

58 In the foregoing we have considered molding conditions but not casting conditions. A description of the latter would be beyond the scope of this paper, but attention is called to the fact that they may at times necessitate a departure from the arrangement which

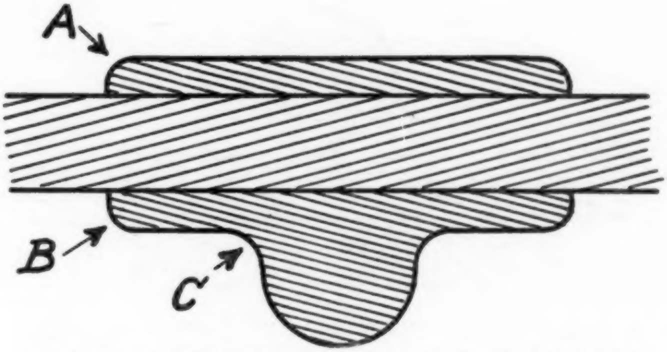


FIG. 20 PLATE PATTERNS WITH ALL CORNERS ROUNDED

would be the most desirable if only the making of the mold had to be reckoned with.

ALLOWANCES FOR DRAFT

59 It is necessary that draft toward the parting line be provided in all cases. A smaller draft is permissible when the pattern is lifted

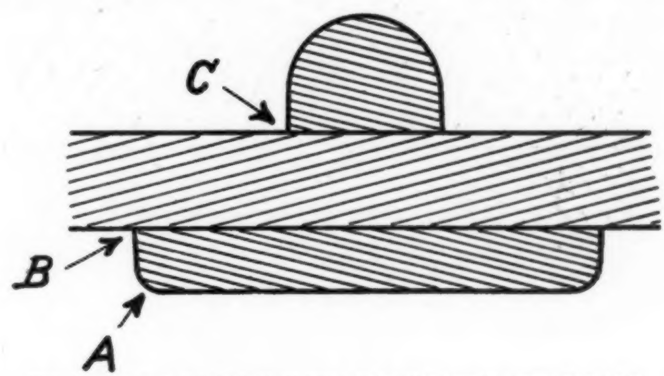


FIG. 21 PLATE PATTERN WITH SOME CORNERS LEFT SQUARE

from the sand, as in the case of "reversible plate" patterns, "split" patterns, and the drag side of all other patterns, than when the mold is lifted off of the pattern, as in the cope-half of all except "reversible plate" patterns and "split" patterns.

60 If the draw is shallow, it is usually desirable to express the draft in degrees, but if the draw is deep, it is better to give dimensions for the top and bottom of the taper. In the first case a slight error in measuring the angle would not sensibly affect the dimensions of

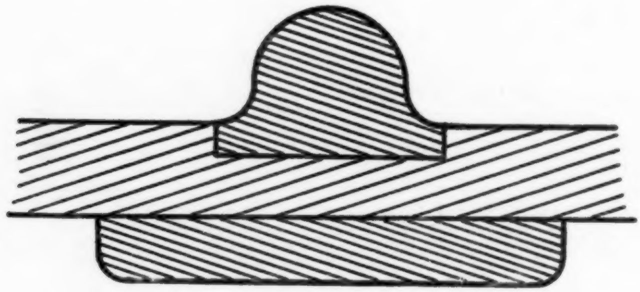


FIG. 22 PATTERN INSERTED IN "PLATE" TO PROVIDE GOOD FILLETS

the piece, while a slight error in the dimensions might change the draft very considerably. In the second case the conditions are exactly reversed.

For those portions of a pattern which are drawn from the sand, the draft should never be less than 1 degree on a side, or 0.02 inch

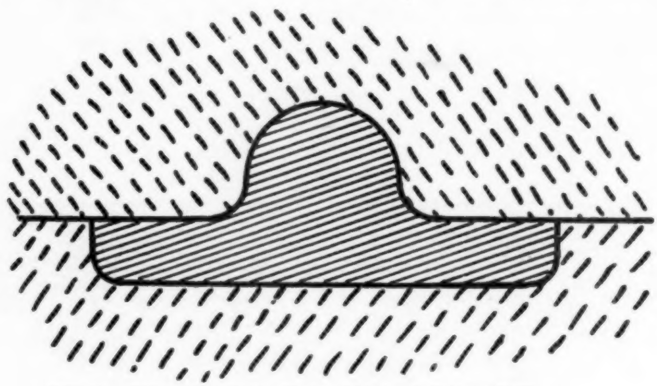


FIG. 23 FILLETS IN "OPEN" CARDED PATTERNS

per inch, on a side. If possible it should be about 2 degrees on a side or 0.03 inch to 0.04 inch per inch on a side.

For those portions of a pattern from which the cope has to be lifted, the draft should never be less than 1½ degrees on a side, or 0.03 inch per inch on a side. If possible it should be about 3 degrees on a side, or 0.05 inch per inch on a side.

ARRANGEMENT OF THE GATES, RUNNERS, RISERS, AND SUPPORTING CONNECTIONS

61 If any portions of the desired casting are very heavy, in comparison with the remaining portions, the gates should be arranged to feed into the heavy parts. The gates should usually be wide and

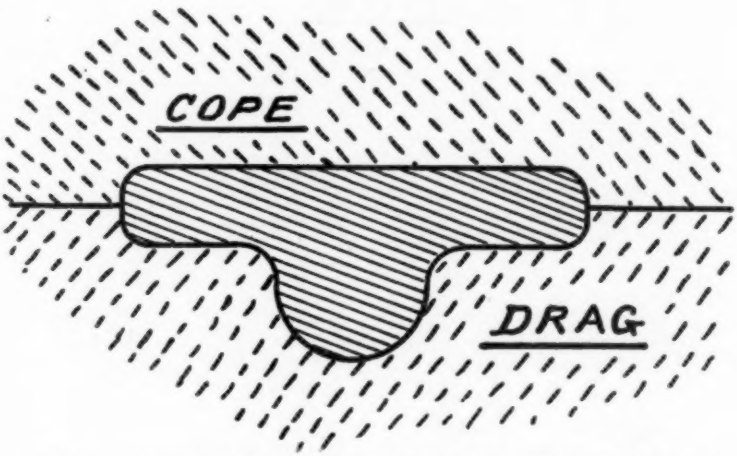
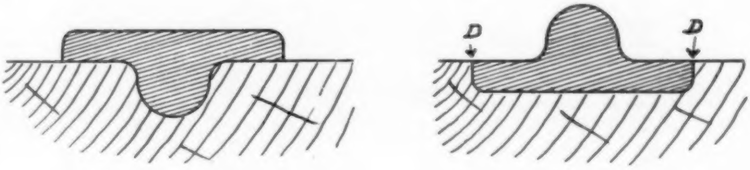


FIG. 24 "OPEN" CARDED PATTERN WITH ALL CORNERS ROUNDED

thin so as to break off easily. If the casting is very light it may be necessary in addition to nick the gate. Care should be taken to leave a good fillet between the nick and the casting itself as shown in Fig. 26 in order to give a clean break at the nick.



Correct parting Incorrect parting

FIG. 25

PATTERNS LET INTO MOLD BOARD

62 To secure uniformity among the castings from any one card, it is desirable to card them all alike, as shown in the upper part of Fig. 27, and not half right and half left, or half at one end and half at the other, as shown in the lower part of the same figure. Shift-

FIG. 26 NICKED GATE

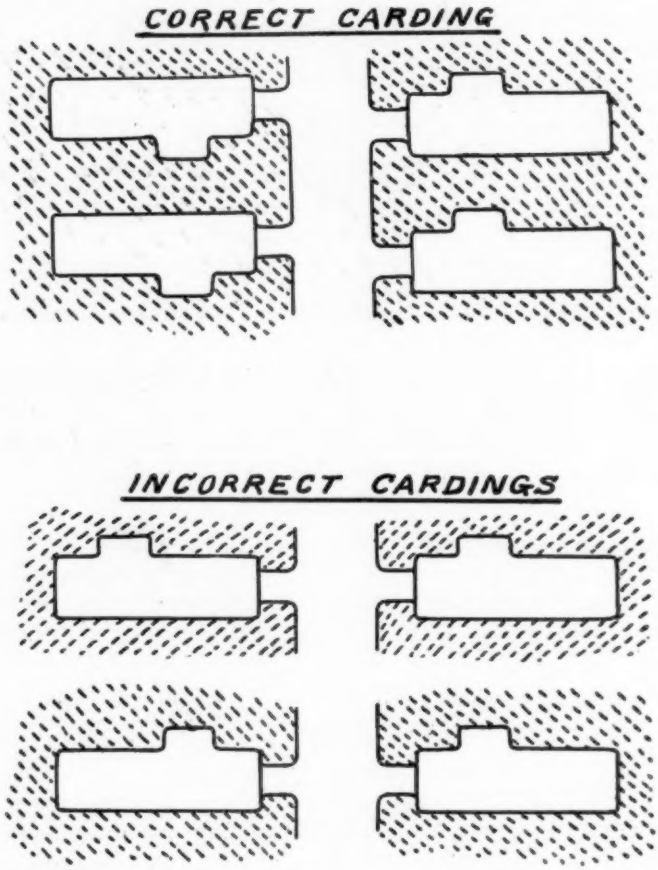


FIG. 27 EFFECT OF CARDING ON UNIFORMITY OF CASTINGS

ing the gate or turning the pattern over may cause variations in the casting, due to the different feeding and cooling conditions. It may also give trouble during machining as the irregularities due to gating come at one point in some of the castings, and at another point in others.

63 To avoid "washing" it is usually desirable to locate the gate in such a way that it will not be in the direct line of flow through the runner. To effect this, the gates may either branch off of the sides of the runner, as in Fig. 27, or if this can not be done, an offset may be provided to check the rush of the metal as in Fig. 28.

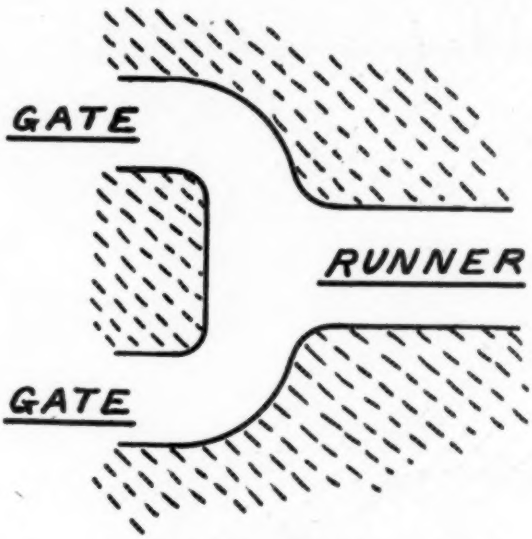


FIG. 28 OFFSET GATES

64 Unless the pouring conditions are such as to require feeding the metal up into the mold from the bottom, the runner should be kept as high as possible, so as to get the best metal into the casting proper. This will usually involve putting the runner into the cope. An excellent cross section for the runner is shown in Fig. 29.

65 The draft on the sides is sufficient to give an easy draw, even though it is in the cope, and the section is heavy enough at all points to prevent danger of chilling. The section, flat on one side and curved on the other, which is sometimes used should be avoided as it is too thin at the edges. A rather neat expedient which sometimes proves helpful is the use of a diamond shaped runner as shown in Fig. 30. If the usual shape of runner had been used, as shown

in Fig. 31, the incline at A would have been entirely too steep, and there would have been a very objectionable hanging pocket of sand at B. The photograph, Fig. 32, shows a runner in which the draft

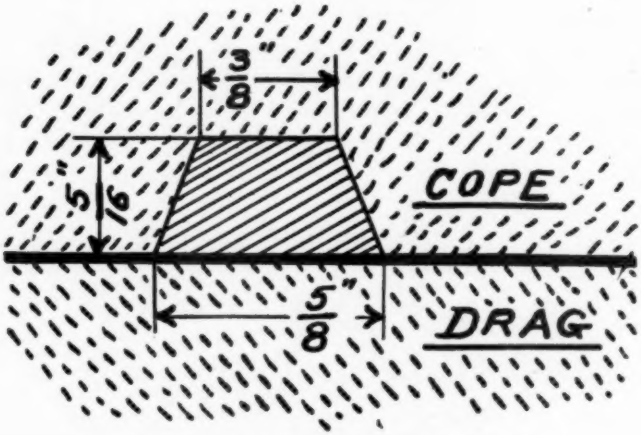


FIG. 29 CROSS SECTION OF RUNNER

was reversed at different points, the mold board rising above the runner in some places, and at others coming only to the bottom of the runner.

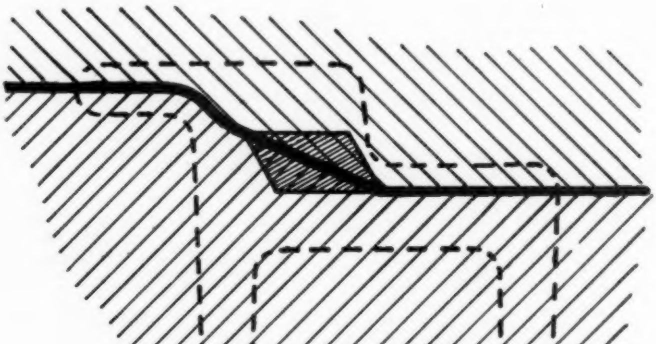


FIG. 30
GOOD PARTING OBTAINED BY USE OF DIAMOND SHAPED RUNNER

66 Fig. 32 also shows an enlargement of the runner at the point where the sprue is to be cut. This enlargement should be about 1 inch in diameter on the cope side. It should be kept in the

exact center of the flask whenever possible, so as to avoid flask weights with pouring holes in special locations. Even if the central location is not possible, the sprue should be kept away from the edge of the flask thus avoiding the danger of the breaking out of the mold.

67 Risers or shrink balls are required only in special cases to avoid piping or excessive shrinkage in heavy parts of the casting. As a discussion of the points at which they are necessary would lead into an entirely unrelated subject, they are merely mentioned here in passing as details which must be provided for when circumstances require them.

68 If the pattern is mounted in a vibrator frame, the latter should always rest on top of the mold board as shown in Fig. 33, and never be let down into it. As the surface of the mold board corresponds

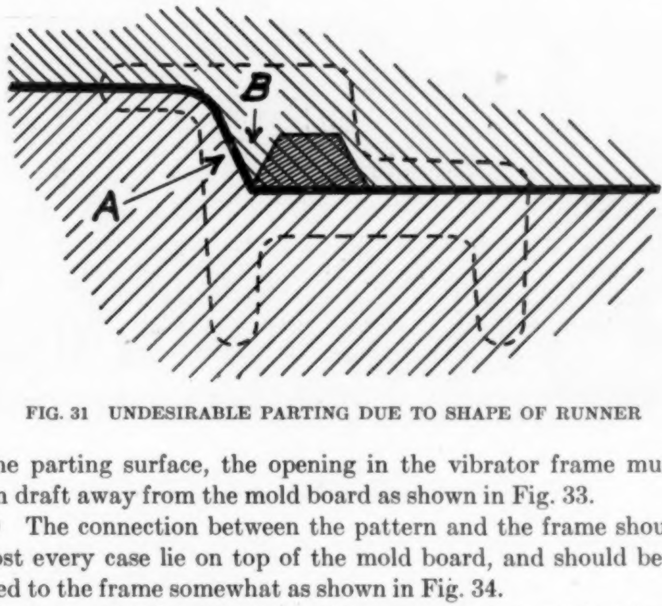


FIG. 31 UNDESIRABLE PARTING DUE TO SHAPE OF RUNNER

to the parting surface, the opening in the vibrator frame must be given draft away from the mold board as shown in Fig. 33.

69 The connection between the pattern and the frame should in almost every case lie on top of the mold board, and should be connected to the frame somewhat as shown in Fig. 34.

70 In snap flask work, it may be necessary to resort to a band in certain cases. This has been treated in detail elsewhere in this article. If a band is placed in the cope it will clear the connection shown in Fig. 34, but if a band is needed in the drag, this form of connection would necessitate a notch in the band at the very point where the plugging of the hole left by the connection leaves the mold the weakest. To avoid this, the connection may be set into the mold board. This will permit the band to come down to the mold board, that is, extend up to the top of the drag, as shown in Fig. 35.

THE MATERIAL OF THE PATTERN AND OF THE RUNNER, PLATE, MOLD BOARD, ETC.

71 For patterns which are used sufficiently to prevent them from rusting, cast iron is by far the best material. It is not only cheap, but it meets the requirements of durability and lightness, and its surface, when free from rust and well waxed, gives a clean draw from the sand. If an iron pattern is out of use for any length of time, it is almost impossible to prevent rust spots, and these spoil the surface very quickly. Of course, the length of time in which an iron pattern may remain idle without rusting depends a good deal on the conditions under which it is stored, and the care taken in cleaning and waxing the pattern before it is put away.

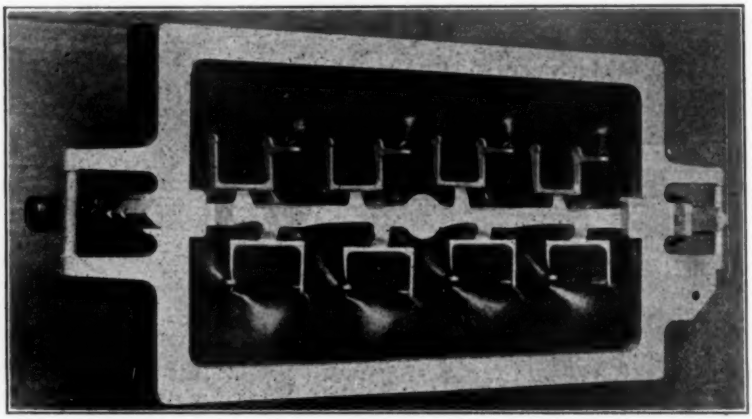


FIG. 32
USE OF DIAMOND SHAPED RUNNER WITH DRAFT REVERSED AT DIFFERENT POINTS

72 If a mold board is used, it is usually desirable to keep the pattern and mold board together. When a wooden mold board is used, a very dry atmosphere shrinks and cracks, while even a moderate amount of humidity increases the liability of the pattern to rust. To avoid changes in the mold board the atmospheric conditions in the pattern storage must be made to correspond, as closely as possible, to those in the foundry. This may compel us, in the case of patterns used only at infrequent intervals, to resort to brass, bronze or other alloys, but all of these are heavier than cast iron and the sand has a greater tendency to stick to them. In the case of large patterns they may also be more costly, but in small patterns the possibility of using

commercial shapes, which require little or no machining, may permit of savings which will more than offset the extra cost of the material.

73 Owing to the ease with which they can be soldered or brazed, the above mentioned alloys may sometimes be desirable for a costly pattern in which extensive changes are likely to be made.

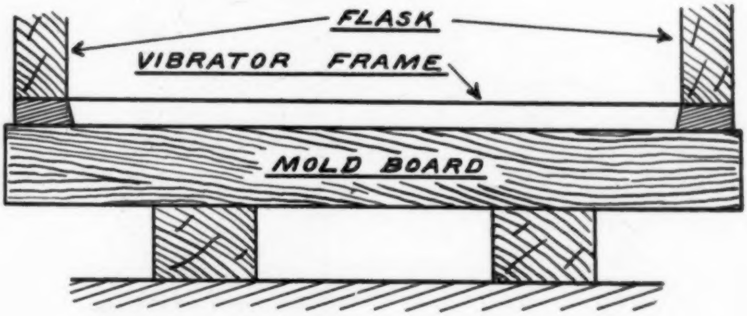


FIG. 33 DIRECTION OF DRAFT IN VIBRATOR FRAME

74 Steel is no better than cast iron in the matter of rusting, and possesses little advantage over brass in weight or cheapness. It is not much used for patterns.

75 Aluminum is not very well suited for the pattern itself, as it is hardly durable enough, and sand has a tendency to stick to it. It is, however, the best material for plates, and for vibrator frames. If made from any other material their weight would be almost prohibitive.

76 Wooden patterns are entirely unsuited for any but the roughest kind of repetition work. Even if the accuracy required is not very

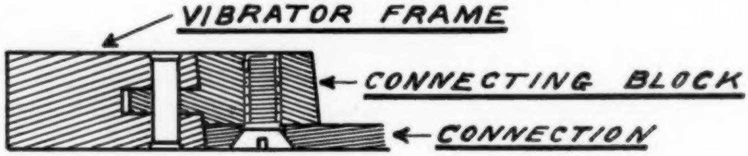
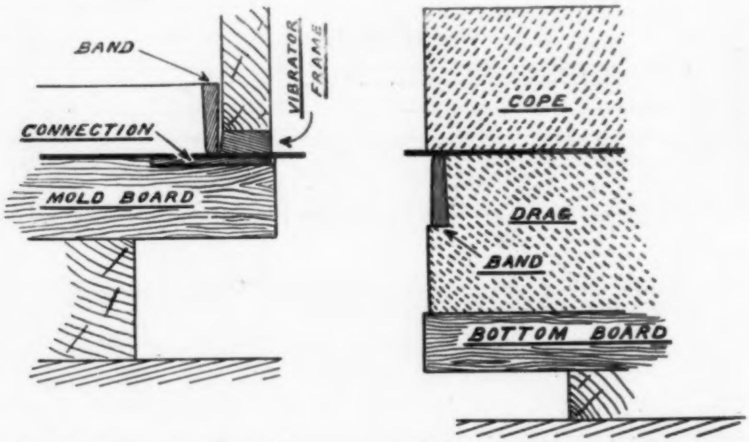


FIG. 34 SUPPORTING CONNECTION FROM PATTERN TO VIBRATOR FRAME

great, it will usually pay better to make metal patterns if a great number of castings is required.

77 For waxing metal patterns a liquid composed of bayberry wax cut with benzine until it is thin enough to apply with a brush, will be found very satisfactory. By painting with this liquid, a pattern can be waxed more quickly and evenly than by the usual process of

heating and rubbing with beeswax. The bayberry wax also gives a superior surface as it dries on in a thin hard coat, free from the stickiness which frequently gives trouble if ordinary beeswax is used. Bayberry wax is used to some extent in pharmacy, and can be obtained from any drug store.



Band testing on mold board   Band in position in the completed mold

FIG. 35 METHOD OF PROVIDING FOR A BAND IN THE DRAG

THE POINTS ON THE PATTERN AT WHICH SPECIAL ACCURACY IS REQUIRED

78 The importance of accuracy at different points on the pattern is indicated by the order followed in the list below:

- A Close clearance points at unmachined portions of the casting.
- B Locating points for the various machining operations.
- C Unmachined surfaces which should bear a fixed relation to each other or to machined portions of the casting.
- D All remaining unmachined portions of the casting.
- E Machined portions of the casting.

79 The machined portions are placed last in the list because a slight variation in the amount of finish can be tolerated. The accuracy of the pattern at the points where no finish is allowed is far more important, because the final dimensions of the casting depend entirely on the pattern. The locating points are also important, for if the castings from different patterns do not correspond at these points, variable results will be obtained from the machining operations.

80 Surfaces which are not machined, or which are used as locating points, should always be placed with reference to each other in such a way as to minimize the danger of incorrect spacing due to the possible cumulation of errors in measuring back and forth on the pattern.

81 Take for example a piece of the shape shown in Fig. 36. The surfaces marked f are to be machined, and the legs are to have a width C after machining. No special accuracy is needed for the distances E and F, as any slight variation will be corrected by the machining. On the other hand, if there are slight variations in G and H the errors might add up, and they might possibly be still further increased by slight errors in J, until the final width between the unfinished surfaces might become greater or less than the desired value D. But as the outside surfaces are machined to the fixed distance $A + 2B$, the thickness C can not possibly come right unless D is right, and a small percentage of error in D would cause a considerable error in the width C. Many a case in which the wall of metal left after machining is entirely too weak, or in which the cutters fail to clean up a boss, or in which they dig in after milling the boss away entirely is due to disregard of these facts.

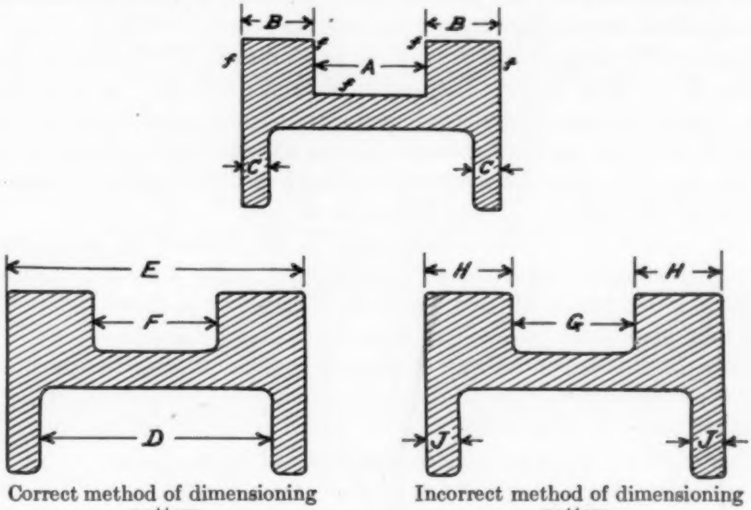


FIG. 36 ARRANGEMENT OF PATTERN DIMENSIONS

82 In entering each dimension care should be taken to make the number of decimal places correspond to the degree of accuracy required, in accordance with the method described in the first part of this paper.

THE AMOUNT OF WORK TO BE EXPENDED ON THE PATTERN

83 The first item to be considered is the outlay on drawings, and there are really only two courses open to us. We can choose between making the drawings and not making them. We can avoid all unnecessary "frills" on them, but if they are made at all, they should be complete and reliable. They should be omitted only in very unimportant patterns, or in the case of patterns which fall into the very lowest grades of the repetition class.

84 In the actual construction of the patterns there is more opportunity for grading the work to suit the requirements, and for devising means of producing the pattern quickly and cheaply. In planning the method of executing the work, we should consider, first the degree of accuracy required, and second the expenditure which will give the most economical relation between investment and earning capacity. Careful attention to the varying degrees of accuracy, indicated on the drawings in the manner already referred to, will enable all unnecessary refinements to be avoided, and with a little ingenuity, labor saving short cuts can almost always be devised.

85 The form of the pattern should be studied to determine whether to build it up, cut it out of the solid, make it from a casting which is machined all over or from a casting machined only at certain points.

86 In the case of built up patterns it is often possible to use commercial brass rods which require no finish, or to use bars of any desired cross section which can be milled to shape accurately and cheaply by means of fly cutters, and then cut up as needed.

87 Many small patterns can be made from a solid bar of brass or cast iron more cheaply than from individual castings. If a pattern is of such a shape that it can best be produced from a casting, it may pay to make an accurately finished metal master pattern, castings from which can be finished up with the minimum amount of machining. Frequently the machining can be omitted altogether, the only finish required being a smoothing up with files and emery cloth. Or certain spots may be machined and the balance smoothed up. Of course, in making castings for this purpose care must be taken to avoid excessive rapping and to use a fine sand which will give the smoothest possible surface. To avoid errors due to hand molding it may also pay to mount the metal master pattern for temporary use on a molding machine.

88 The relation between working patterns, master patterns and grand master patterns can perhaps be brought out most clearly by

quoting the following rules which the author drew up some years ago, and which have been followed since that time with good results:

Rules

89 All patterns will be classed under one of the three following heads: *a* Working patterns. *b* Master patterns. *c* Grand master patterns.

Working patterns used for *Repetition work* shall be of metal, and in most cases mounted for use on the molding machines.

Working patterns used for *experimental work*, or for *jobbing work* shall be, in most cases, of wood. When practicable, they shall be arranged for temporary mounting for use on the molding machines.

Master patterns may be of wood or metal, according to circumstances. When the piece to be produced permits, the working patterns shall be made by smoothing up castings taken from a metal master pattern. In cases in which it is preferable to machine the working patterns, the master pattern usually shall be of wood.

Grand master patterns shall be of wood, or if made of metal shall be built up out of stock material. They shall be used in cases where it is necessary to obtain a casting out of which to make a metal master pattern.

Excepting in special cases, for which special provisions are made, the following general instructions shall be observed in making patterns and in making drawings for them.

METAL WORKING PATTERNS

Metal working patterns are the standard patterns for repetition work.

They are *made from drawings* showing the finished dimensions of the pattern itself. These drawings will be dimensioned to cover all necessary allowances for finish, shrinkage, and draft, and there will be no further allowance in making the pattern.

They are *made by* smoothing up castings obtained from the metal master pattern, or by machining castings obtained from the wooden master pattern, or by building up out of stock material.

They are *mounted* for use on the molding machines in accordance with the carding drawing.

They are *stamped* on the runner with the part number of the first piece produced from this casting. If one casting is machined to make several different pieces, the pattern will still have only one pattern number, which will be identical with the part number of the first piece produced. Each card will have a distinguishing mark, usually one dot on the first card, two on the second, etc., which will be placed so as to be visible in the casting even after it is machined. This mark will be in each pattern of the card, and alike in all patterns of any one card. Even if there is only one card, the distinguishing mark is to be put on it, as another card might be made later.

WOODEN WORKING PATTERNS

Wooden working patterns are the standard patterns for experimental or jobbing work.

They are *made from drawings* showing the finished dimensions of the piece,

The pattern must, therefore, be made with allowance for single shrinkage, draft and finish, as noted on the drawing.

They are *mounted* for use on the molding machines whenever practicable.

They are *stamped* with the pattern number, which corresponds to the number of the finished piece. If one casting is machined to make several different pieces, the pattern will still have only one pattern number corresponding to the number of the first piece produced from it.

Particular attention is directed to the fact that patterns for runners fall under this heading and must comply with these requirements.

METAL MASTER PATTERNS

Metal master patterns are used to obtain castings suitable for use as working patterns after they have been smoothed up, or used in cases in which a wooden master pattern would not be durable enough.

They are *made from drawings* showing the finished dimensions of the metal master pattern itself. These drawings will be dimensioned to cover all necessary allowances for finish, shrinkage and draft, and there is to be no further allowances made when making the pattern.

They are *made of* castings obtained from the grand master pattern, or by building up out of stock material.

They are *mounted* temporarily for use on the molding machines to facilitate the obtaining of good castings.

They are *stamped* with the pattern number.

WOODEN MASTER PATTERNS

Wooden master patterns are used in cases in which the metal working pattern has to be machined.

They are *made from drawings* showing the finished dimensions of the metal working pattern. Allowance for single shrinkage, and an additional allowance for finish all over must be provided when making the pattern.

They are *mounted* temporarily for use on the molding machines when practicable.

They are *stamped* with the pattern number.

GRAND MASTER PATTERNS

Grand master patterns are needed only in cases in which a metal master pattern has to be made out of a casting.

They are *made from drawings* showing the finished dimensions of the *metal master pattern.* Allowance for single shrinkage and an additional allowance for finish, as marked on the drawing, must be provided when making the pattern.

They are *mounted* temporarily for use on the molding machines when practicable.

They are *stamped* with the pattern number.

90 The distinguishing mark on each pattern which is referred to in the rules above quoted is provided for the purpose of identifying the card from which a given casting was produced. This is a necessary feature if duplicate sets of patterns are run.

91 In discussing the flask sizes, reference has already been made to the use of a few patterns in a small flask for such patterns as would not warrant a larger pattern equipment. And even if a smaller flask is not practicable or desirable, it may often pay to make and card only a few patterns, leaving the balance of the mold unused, in preference to spending money in the tool room which the saving in the foundry might not offset in years.

92 When undertaking new work it is always a wise precaution to make and card only a part of the patterns, leaving the balance to be added later so as to facilitate the making of any changes or improvements which may suggest themselves in turning out the first few lots.

93 In the same way, if it is desirable to put through a limited number of castings from a new pattern to test out the tool equipment, much valuable time can often be saved by getting the castings as soon as a single pattern can be made and carded. The remaining patterns of the card can be added later.

94 If a portion of the mold is unused, do not spread out the patterns. Card the ones which are nearest to the sprue, and keep them close together to avoid waste of metal in the runner.

95 It is usually false economy to mount two or more different patterns on one card. Even if it seems that the proportion in which they will be used can be definitely fixed, for instance in the case of rights and lefts, unforeseen circumstances may arise at any time to upset the calculation. Repair orders may be heavier for one casting than for the other, or a batch of work from one casting may be spoiled and have to be scrapped, or the loss in the foundry or in the factory may be heavier for one than for the other. These and similar conditions may make it necessary to increase the output on one of the castings, and this is always troublesome and wasteful if different patterns are mounted on a single card.

96 One detail which it is necessary to watch is the tendency to "save time" by being careless in regard to the radii of fillets and rounds. A fillet is often difficult to produce, but that is no reason for shirking the work on it. Pattern makers should be provided with radius and fillet gages, and should be made to work to them.

97 The guide pins on each "plate," frame, etc., should be carefully fitted to a gage so as to ensure squareness and accurate spacing. A single adjustable gage with a series of doweled settings may be used to cover the entire range of flask sizes.

98 If careless work is permitted in the fitting of these pins, the foundry is driven to a more or less ineffectual tinkering of the flask

pins every time a pattern is changed. If proper precautions are taken to maintain the standard, all patterns and flasks of the same size will be perfectly interchangeable. A little graphite (not oil) should be used to lubricate the pins, and the fit should be as tight as is consistent with a smooth lift.

FOUNDRY BLOWER PRACTICE

By WALTER B. SNOW, BOSTON, MASS.
Member of the Society

Modern foundry practice in the melting of metals is fundamentally dependent upon the blower. As the successor of the blowpipe and the bellows, it has made possible the massing of fuel in large quantities, with greater imposed resistance, the production of higher temperatures, and the better utilization of the heat in the furnace.

2 The primary function of a blower is to move air against resistance. Its performance is dependent upon the relation expressed by the formula:

$$V = \sqrt{2gh} \qquad [1]$$

in which V = velocity in feet per second
h = head in feet
g = acceleration due to gravity = 32.16

or

$$V = \sqrt{2g\frac{p}{d}} \qquad [2]$$

when h is expressed in terms of p = pressure and d = density.

3 When applied under the conditions of

p = pressure in ounces per square inch
d = density or weight per cubic foot of dry air at 50

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degrees fahr. and under atmospheric pressure of 14.69 pounds or 235 ounces = 0.077884 pounds, formula [2] becomes

$$V = \sqrt{64.32 \times \frac{p \times 144}{16 \times 0.077884 \times \frac{235 + p}{235}}} \qquad [3]$$

which reduces to

$$V = \sqrt{\frac{1746659 \times p}{235 + p}} \qquad [4]$$

Allowance is evidently made therein for compression of air but not for change of temperature during discharge.

4 The velocities in the basis Table 1 were calculated by this formula.

5 The tabulated volume is in each case the product of velocity and effective area.

TABLE 1

Relations of Pressure, Velocity, Volume and Horse Power

Pressure per sq. in. ozs.	Velocity of dry air at 50 degrees fahr. escaping into outer system through any shaped orifice		Volume discharged in one minute through an orifice having effective area of one sq. in. cu. ft.	Horse power required to move given volume under given conditions
	Feet per sec.	Feet per sec.		
1	86.03	5 161.7	35.85	0.00978
2	121.41	7 284.4	50.59	0.02759
3	148.38	8 902.8	61.83	0.05058
4	170.98	10 258.6	71.24	0.07771
5	190.76	11 445.5	79.48	0.1084
6	208.53	12 511.9	86.89	0.1422
7	224.77	13 486.4	93.66	0.1788
8	239.80	14 387.9	99.92	0.2180
9	253.83	15.229.6	105.76	0.2596
10	267.00	16 020.4	111.25	0.3034
11	279.70	16 768.1	116.45	0.3493
12	291.30	17 478.2	121.38	0.3972
13	302.59	18 155.2	126.06	0.4470
14	313.38	18 802.7	130.57	0.4986
15	323.73	19 423.6	134.89	0.5518
16	333.68	20 020.7	139.03	0.6067
17	343.26	20 595.8	143.03	0.6631
18	352.52	21 151.0	146.88	0.7211
19	361.46	21 687.8	150.61	0.7804
20	370.13	22 207.5	154.22	0.8412

6 The theoretical horse power is the product of pressure, velocity and effective area.

7 For refined work, or under conditions of wide variation from the basis of the table, corrections should be made for differences in humidity and temperature.

8 In the ordinary processes of the foundry, where iron or the less refractory metals are to be reduced, the resistance of the crucible, air, or cupola furnace will roughly range from somewhat above one ounce to a possible but usually unnecessary pressure in excess of 20 ounces per square inch.

9 Up to about 8 ounces the fan blower cannot be excelled for convenience and efficiency. From 8 to 16 ounces the field is fairly divided between the fan and the rotary types, the advantage gradually shifting from the former to the latter as the pressure increases. Above 16 ounces the superiority of the rotary type is manifest, until it in turn encroaches upon the efficient field of the blowing engine at about 5 pounds; a pressure far in excess of the practical requirements of the foundry. The air compressor, as an aid to combustion, is economically useful only in connection with the burning of liquid fuel.

10 The fundamental differences between the fan and the rotary type of blower lie in the manner of creating pressure and in the effect of resistance.

11 In the fan type, velocity is given to the air in its passage from the inlet to the circumference of the revolving wheel. This is transformable into pressure with corresponding density within the enclosing case and connections; the pressure being dependent upon the number of revolutions. In the case of a fan blower at constant speed, the volume and power decrease as the resistance increases. When the outlet is closed, the wheel continues to revolve at the same speed, but without effective delivery, and with minimum power expenditure.

12 In the rotary, or so called "positive" type, air in regularly succeeding volumes is imprisoned by one or more enclosed revolving impellers, and forced forward against the imposed resistance. It is thereby compressed to a density, and given a pressure proportionate to that resistance. This pressure is fundamentally independent of the number of revolutions. The delivery remains practically constant for a given speed as long as discharge is permitted, while the power expenditure increases with the resistance. When the outlet is closed, the power required is at the maximum, and the displacement, though ineffective, is just equal to the slip; up to the limit of power to drive and of strength to endure.

13 The construction and proportions of a prevalent type of cupola fan blower are illustrated in Fig. 1. The casing and wheel are provided with two inlets, which, in ordinary construction, are about one half the diameter of the wheel. The width of such a wheel at its periphery ranges from 5 to 8 per cent of the diameter, the width between side plates at the inlet being approximately one sixth of the diameter. From 6 to 8 major blades extend from inlet to circumference; between these are one, two or three times as many minor blades of about one half the radial length. All blades are slightly curved backwards at the circumference of the wheel. The cast iron casing is of involute form, its greatest diameter being approximately $1\frac{3}{4}$ times the diameter of the enclosed wheel.

14 In the volume type, designed for much lower pressures, such as are required in air furnace operation, the peripheral width of the wheel ranges from 20 to 40 per cent of its diameter. The casing is often of steel plate.

15 Refined consideration of blower design is not necessary in a discussion of foundry blower practice, but a knowledge of fundamental principles and empirical relations is essential to a clear understanding of the subject.

16 The manufacturers' rating of the type of blower shown in Fig. 1 is based upon the greatest effective area over which it will maintain the maximum velocity of discharge. As originally established by Sturtevant, this "capacity area" or "square inches of blast" is represented by the empirical formula

$$\text{Capacity area} = \frac{DW}{3} \qquad [5]$$

in which D = diameter of wheel in inches
W = width of wheel at circumference in inches.

17 This formula was derived from the pressure type of fan blower The value of the divisor must necessarily vary with the proportions of the wheel, the number of inlets, the number and curvature of the blades, and the form of the enclosing case. But as a merely arbitrary basis, the formula has been generally accepted for the ready comparison of wheels of substantially the same type.

18 Manifestly the maximum velocity of discharge will create the maximum total pressure. As a factor in the manufacturers' rating this attainable velocity has been accepted as being equal to the circumferential speed of the wheel. This assumption is by no means universally correct.

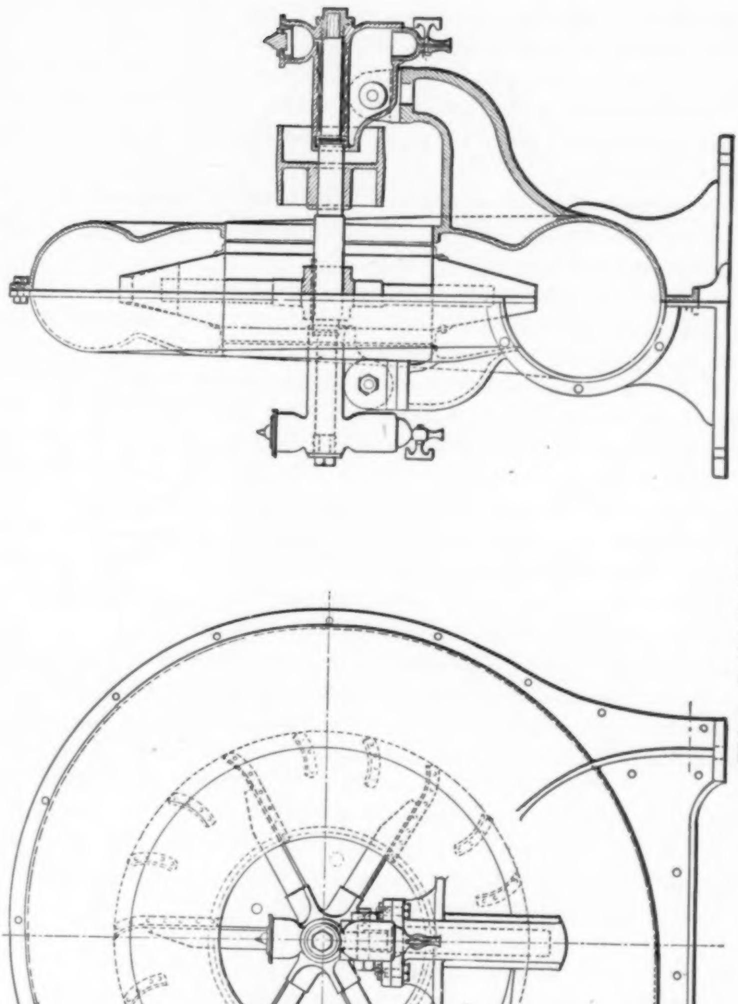

FIG. 1 FAN BLOWER

19 Recent developments in fan construction with very large inlets, numerous shallow blades, and unusual width, show discharge velocities far in excess of the circumferential speed, approximating a theoretical maximum of twice that speed. But successful application of such fans has not yet been made under the resistance obtaining in cupola practice.

20 It is evident that, disregarding the effect of changes in density and temperature, the following relations should hold for a given fan with constant capacity area:

a the volume varies directly as the revolutions,

b the pressure varies directly as the square of the revolutions,

c the power varies directly as the cube of the revolutions.

21 These relations clearly point to the economic desirability of closely proportioning the fan to the work it is to perform. An increase of only 25 per cent in the speed, which may be necessitated by deficiency in the volumetric capacity of a given fan, nearly doubles the power required, and creates a pressure more than 50 per cent in excess of that at normal speed. It is seldom that the sum of fixed charges and operating expense cannot be materially reduced by substituting a larger and more costly fan for one that must be run at unnecessary speed to deliver the required volume.

22 The speed of a fan is usually fixed, and variations occur only in the effective area of discharge. In cupola practice such variation is extensive, and changes often succeed each other with frequency. Hence it is difficult to proportion the fan to secure the most economical average performance. It must have capacity to deliver the required volume under the greatest resistance, toward the end of the heat, but the power provided must be sufficient to drive it during the early part of the heat when there is less resistance, greater delivery and consequently more work to be done.

23 For the ordinary type of fan it has been generally accepted that within the capacity area

a The velocity and pressure are maximum and constant.

b The volume and horse power are proportional to the area.

24 These relations are only approximate, as is evident from Fig. 2. The curves are characteristic of an individual instance in which the fan ran at constant speed while discharging through various outlet areas. All values are relative to the performance at capacity area. Changes in the proportion or the speed of the fan would materially affect these relations, causing them to approach or recede from the conditions expressed in the preceding paragraph, and shifting the point of maximum efficiency.

25 These curves serve to show that

a Maximum efficiency in power and pressure are secured at or near the capacity area.

b The power per unit of volume and the pressure decrease as the discharge area and volume increase.

c With closed outlet the power is approximately one third of that at capacity area.

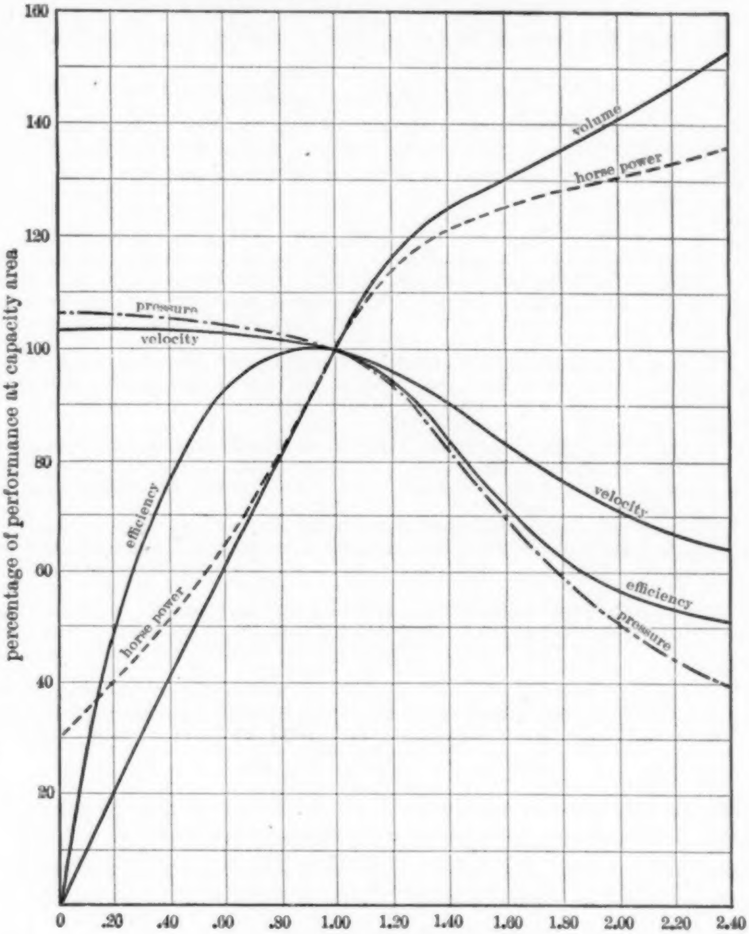

FIG. 2
RELATIVE PERFORMANCE OF A FAN AT CONSTANT SPEED WITH VARIABLE OUTLET AREA

26 From the preceding it must be manifest that no simple exact basis of calculation can be established for varying fan proportions

and conditions. For all practical purposes, however, the manufacturer's basis, although only approximately correct, is sufficiently accurate, particularly in cupola practice, where operation at or near the capacity area is essential.

27 Upon this basis Table 2 has been calculated to show the performance at capacity area per inch of peripheral width of typical diameters of cupola fan blowers. Basic values are taken from Table 1, the air being dry, and of 50 degrees fahr. temperature; the velocity of discharge is taken as equal to the circumferential speed of the

TABLE 2

PERFORMANCE OF CUPOLA FAN BLOWERS AT CAPACITY AREA PER INCH OF PERIPHERAL WIDTH

DIAM. OF WHEEL INCHES CAP. AREA SQ. INS.	ITEM	TOTAL PRESSURE IN OUNCES PER SQUARE INCH										
		6	7	8	9	10	11	12	13	14	15	16
18 in. 6 sq. in.	r.p.m.	2660.0	2860.0	3050.0	3230.0	3400.0	3560.0	3710.0	3850.0	3990.0	4120.0	4250.0
	cu. ft.	520.0	560.0	600.0	640.0	670.0	700.0	730.0	760.0	780.0	810.0	830.0
	h.p.	1.7	2.1	2.6	3.1	3.6	4.2	4.8	5.4	6.0	6.6	7.3
24 in. 8 sq. in.	r.p.m.	2000.0	2150.0	2290.0	2420.0	2550.0	2670.0	2780.0	2890.0	2990.0	3090.0	3190.0
	cu. ft.	700.0	750.0	800.0	850.0	890.0	930.0	970.0	1010.0	1040.0	1080.0	1110.0
	h.p.	2.3	2.9	3.5	4.2	4.9	5.6	6.4	7.1	8.0	8.8	9.7
30 in. 10 sq. in.	r.p.m.	1590.0	1720.0	1830.0	1940.0	2040.0	2140.0	2230.0	2310.0	2390.0	2470.0	2550.0
	cu. ft.	870.0	940.0	1000.0	1060.0	1110.0	1160.0	1210.0	1260.0	1310.0	1350.0	1390.0
	h.p.	2.8	3.6	4.4	5.2	6.1	7.0	7.9	8.9	10.0	11.0	12.1
36 in. 12 sq. in.	r.p.m.	1330.0	1430.0	1530.0	1620.0	1700.0	1780.0	1850.0	1930.0	2000.0	2060.0	2120.0
	cu. ft.	1040.0	1120.0	1200.0	1270.0	1340.0	1400.0	1460.0	1510.0	1570.0	1620.0	1670.0
	h.p.	3.4	4.3	5.2	6.2	7.3	8.4	9.5	10.7	11.9	13.2	14.5
42 in. 14 sq. in	r.p.m.	1140.0	1230.0	1310.0	1380.0	1460.0	1530.0	1590.0	1650.0	1710.0	1770.0	1820.0
	cu. ft.	1220.0	1310.0	1400.0	1480.0	1560.0	1630.0	1700.0	1770.0	1830.0	1890.0	1950.0
	h.p.	3.9	5.0	6.1	7.3	8.5	9.8	11.1	12.5	13.9	15.4	17.0
48 in. 16 sq. in.	r.p.m.	1000.0	1070.0	1150.0	1210.0	1270.0	1330.0	1390.0	1450.0	1500.0	1550.0	1590.0
	cu. ft.	1390.0	1500.0	1600.0	1690.0	1780.0	1860.0	1940.0	2020.0	2090.0	2160.0	2230.2
	h.p.	4.5	5.7	7.0	8.3	9.7	11.2	12.7	14.3	15.9	17.7	21.0

wheel, and the power, as double the theoretical. While 50 per cent efficiency is below that which may be attained in good cupola installations, it is always desirable to provide ample surplus above the power required at capacity area. Even a change of 50 degrees from the ordinary inlet temperature makes a difference of about 10 per cent in the power.

28 Characteristic types of single and double impeller rotary blowers are presented in Figs. 3 and 4. Numerous other designs are, or have been, in use.

29 In the type shown in the skeleton cross-section in Fig. 2, the single impeller is made up of three diamond shaped blades extending from a central web. On either side of the web a stationary core fills the space within the inner circumference of the blades, forming in connection with the enclosing case an annular space within which they revolve. The rotor which co-incidentally revolves in the smaller

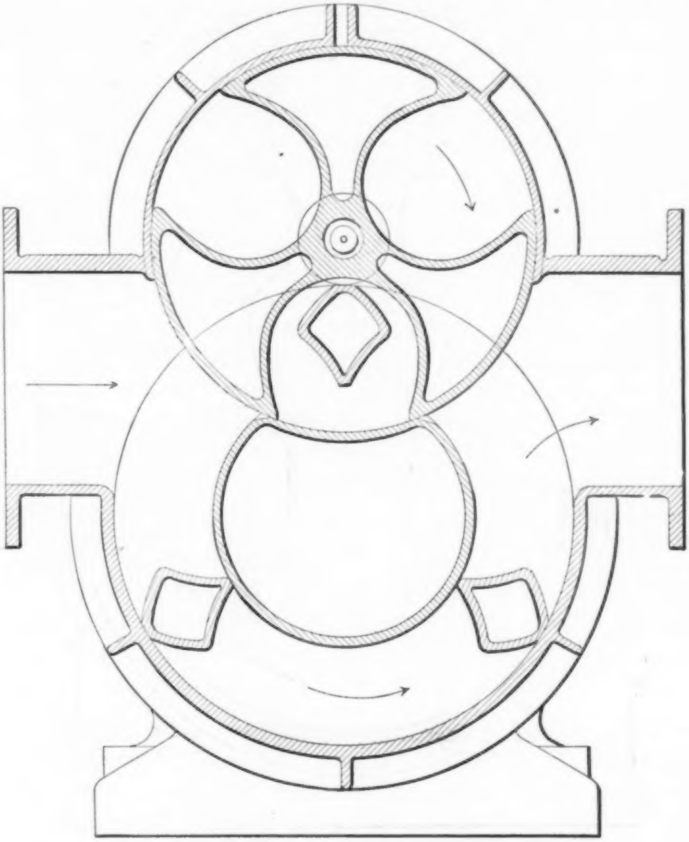

FIG. 3 ROTARY BLOWER
SINGLE IMPELLER, TRIPLE BLADED TYPE

portion of the casing, successively provides pockets to receive and pass the revolving impeller blades to the suction side of the blower, without allowing the escape of compressed air. The rotor is in effect an idler which calls for no power expenditure other than that required to overcome friction.

30 In the type shown in Fig. 4, both impellers are symmetrical and counterparts of each other. The surfaces are so formed, and the. impellers are so located on their respective shafts, as to permit of rotation with uniform clearance, and without metallic contact.

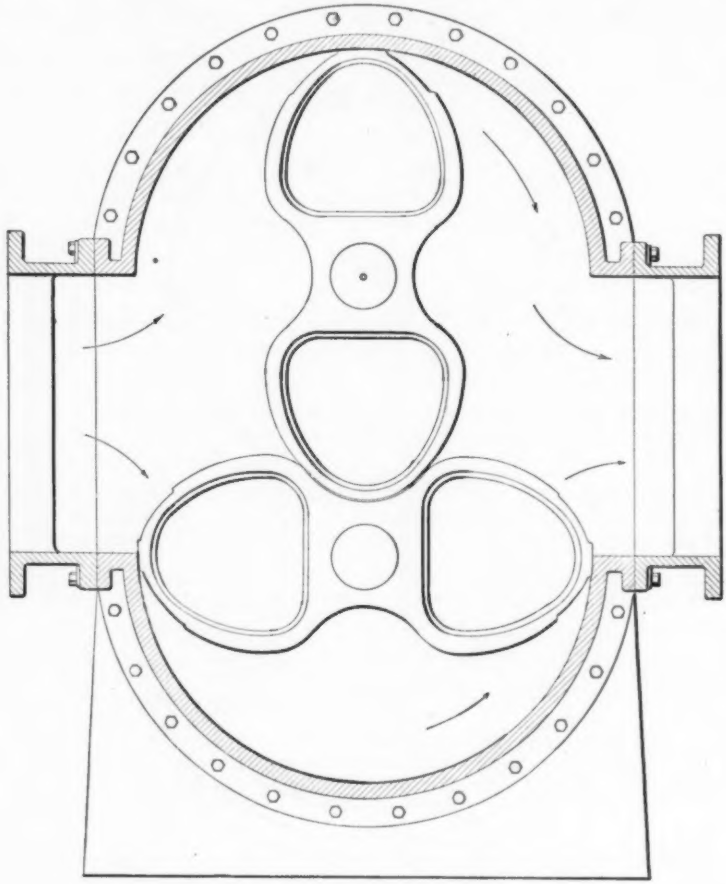

FIG. 4 ROTARY BLOWER
DOUBLE IMPELLER TYPE

Release of air on the discharge side of each impeller is practically coincident with the cut-off of admission on the inlet side.

31 In both types, the air passing through the inlet is imprisoned, and carried forward to the outlet side. Here it meets and mingles with an air of greater density, already compressed by previous action

of the impellers. Equalization of pressure instantly results. As a consequence, there is more or less fluctuation coincident with the revolutions of the blower. The degree of fluctuation depends upon the ratio between the released volume and the total volume under compression, and also upon the extent to which the air has been previously compressed in transit through the blower. This occurs in the case of the single, but not of the double impeller type here illustrated.

32 The theoretical relations which prevail in the case of a rotary blower having a fixed free area of discharge and no slip, are identical with those already specified for the fan type operating within its capacity area, namely; the volume, and consequently the velocity, vary as the number of revolutions, the pressure varies as the square, and the power as the cube of the revolutions. But here the similarity ends, for in the fan the number of revolutions is an essential function of the pressure, while in the rotary blower they are entirely independent. In other words, material change of total pressure with the fan type can only be secured within the capacity area by change in revolutions, while with the rotary type, great range in pressure is attainable, at constant revolutions by merely varying the resistance.

33 Under conditions of constant speed, and variable outlet or resistance, the performance relations of a theoretically perfect rotary blower are as follows, the effect of changes in temperature and density being disregarded:

a The volume is constant.
b The velocity varies inversely as the effective outlet area.
c The pressure varies inversely as the square of the outlet area, hence as the square of the velocity.
d The power varies directly as the pressure.

34 But the mechanical necessity of clearance, and the consequent slip or backward leakage, affect these relations particularly as the conditions depart from the field of maximum efficiency. The slip is theoretically, and in practice, approximately proportional to the square root of the pressure difference between the atmosphere and the imprisoned air, that is, to the velocity which it creates. It therefore results that the volumetric efficiency decreases as the pressure increases.

35 Fig. 5 presents characteristic curves showing relative performance of a single impeller blower of the type illustrated in Fig. 3. The rapid drop in mechanical efficiency at pressures below one-half pound is manifest.

36 The performance of a two impeller type, like Fig. 4, at different speeds and resistances, is illustrated by the curves in Fig. 6. Volumes and horse powers are relative.

37 Under specific conditions of constant speed and resistance, it might be possible to establish the superiority of one type of blower above the other, based primarily upon first cost and operative efficiency. But conditions vary as do blowers, which for commercial

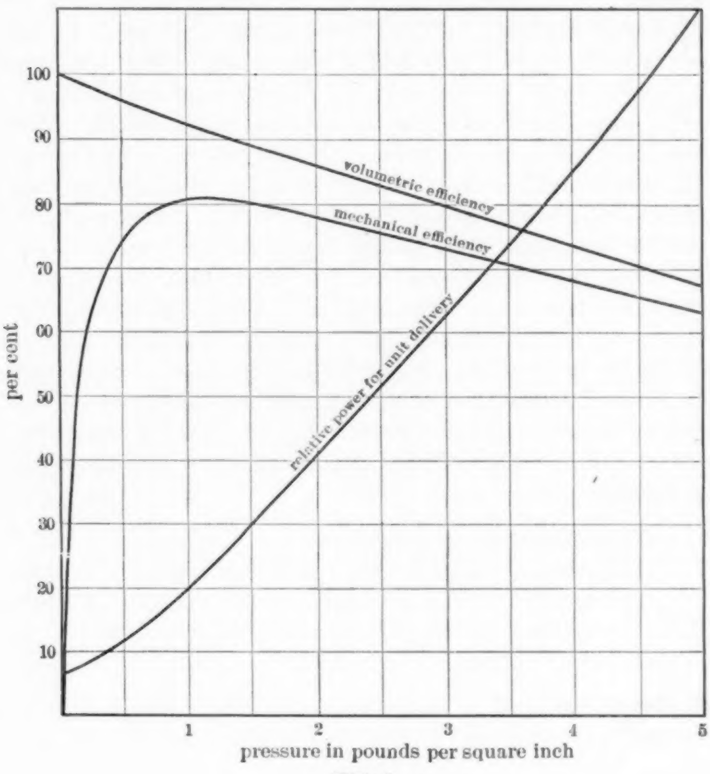

FIG. 5

RELATIVE PERFORMANCE OF A SINGLE IMPELLER ROTARY BLOWER AT CONSTANT SPEED WITH VARIABLE RESISTANCE

reasons are built in stated sizes from which selection must be made. Hence the problem is complicated, and the solution becomes to a considerable degree dependent upon the intangible factor of "adaptability."

38 With no purpose of definition as to advantages or disadvantages, the characteristics of the two types operating within practical limits may be thus summarized and contrasted:

39 With a fan blower the maximum pressure is determined by the number of revolutions; with a rotary blower it depends upon existing resistance or the weighting of the relief valve.

40 The volume discharged by a fan blower is dependent upon the

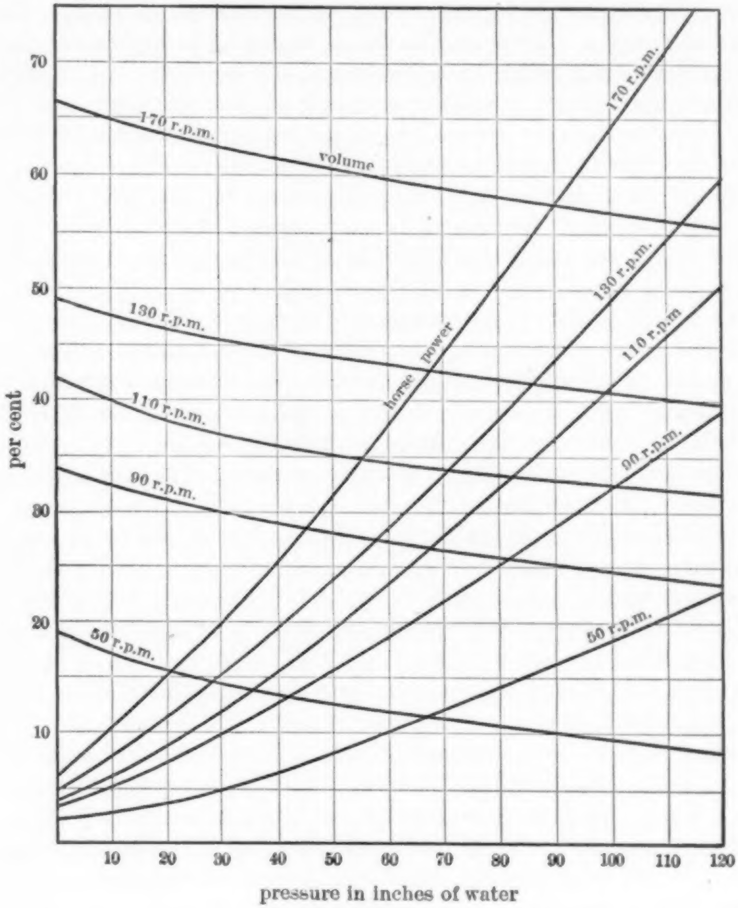

FIG. 6

RELATIVE PERFORMANCE OF A DOUBLE IMPELLER ROTARY BLOWER AT VARIOUS SPEEDS AND PRESSURES

outlet area and the corresponding pressure; in the rotary type it is independent of both.

41 The maximum power is required when a fan blower discharges against the least, and when a rotary blower discharges against the greatest resistance.

42 The fan blower automatically increases the created pressure as the opposing resistance becomes greater, until it equals the maximum pressure capacity of the fan. The volume, although coincidentally decreased, is rendered effective by the greater pressure, while the power is roughly proportional to the effective work. The rotary blower is likewise automatic up to the limit of pressure temporarily established by the resistance of the relief valve, but without material change of volume, and with increase in power. Above the pressure limit set by the valve, air escapes to the atmosphere, and the power expended thereon has no useful effect.

43 The weight and cost of a fan blower are far less, and the speed far higher than in the case of a rotary blower; at low pressures the efficiency of the fan is superior while at the higher pressures necessary in the cupola, the rotary type excels.

44 As the total head or pressure created by a blower represents the sole means of producing movement of the air, whatever portion of this head is consumed in overcoming the frictional resistance of piping and fuel, reduces by just so much the amount remaining available for the production of velocity. The greater the ratio between the surface of a pipe, and the quantity, and the higher the velocity, the greater is the resistance.

45 Were the outlet in the casing of a fan blower to be made equivalent to the capacity area, the velocity and corresponding friction would be excessive. But in both the fan and rotary types, the area of the outlet is such that the velocity of discharge seldom exceeds 3000 feet per minute. Even this is so great that material saving in power may be secured in a long pipe by making its area considerably in excess of the blower outlet. For instance, the frictional loss in 100 feet of 10 inch pipe with 3000 feet velocity will be practically 1 ounce; while that in a 12 inch pipe, passing about the same volume at 2000 feet velocity, will be approximately $\frac{3}{8}$ ounce.

46 If a certain velocity pressure is required at the point of final delivery, it is manifest that the blower, if in a distant location, must create a total pressure sufficiently in excess to allow for the loss by friction. A drop of a couple of ounces is not uncommon with an ordinary piping system.

47 The actual conditions in a conduit may be determined by a Pitot tube, and calculations of volume made therefrom. The most satisfactory form of instrument appears to be that devised by Mr. D. W. Taylor, and described in his paper before the Society of Naval Architects and Marine Engineers, November 1905. Care must be exercised in the use of any form of pressure gage in order to avoid mis-

leading readings. This is particularly true regarding determination of pressure in the wind-box of a cupola, wherein the direction of air currents is uncertain.

48 The modern cupola furnace is typical of metallurgical progress in which conservation of heat has been secured by massing fuel and metal. As arranged in successive charges with a melting zone of maximum temperature beneath, the best possible opportunity is presented for the gradual ignition of the fuel, and heating of the metal in their downward course.

49 It would at first appear that equal facility was provided for securing complete combustion, and that the quantity of air furnished might closely approximate the chemical requirements. But to secure the best results the volume is reduced in practice considerably below that theoretically required; of necessity incomplete combustion results. The conditions are closely similar to those in the blast furnace.

50 The reason for this condition is to be found in the arrangement of the superimposed charges of fuel and metal with relation to the air supply, which necessitates passing through the lower charges all of the air required for those above. Although perfect combustion with an excess of air is thereby secured in the melting zone, the tendency of excessive dilution is to cool the gaseous mixture to a temperature even below that of the molten iron. Under such conditions less heat is transferred to the upper changes, because of the higher velocity and lower temperature of the gases.

51 The air supply to a cupola is not, therefore, to be determined by the chemical requirements of the entire body of fuel, but by the excess which the lower charges are able to endure without disastrous cooling. The level of the ignition zone, and the completeness of combustion, are necessarily limited by this excess.

52 The introduction of two or more rows of twyers with large aggregate area, has served to distribute the air admission, to reduce the cooling effect in the melting zone, to raise the level of the ignition zone, and to perfect the combustion. But a coincident—and otherwise beneficent—increase in the height of the changing door has still prevented the attainment of complete combustion, although a larger proportion of the heat is utilized.

53 Authoritative chemical analysis of the escaping gases are exceedingly rare, but such as are available show that only about 50 per cent of the carbon combines to form carbon dioxid. The balance escapes as an element of carbon monoxid having less than one-third of the heat value. In other words only about two-thirds of the pos-

sible heat of combustion is utilized. This indicates a shortage of about 25 per cent in the air supply.

54 The intermittent operation of the ordinary cupola is not conducive to the ready utilization of the waste heat by external means, as is possible in the case of the blast furnace. Further economy is therefore to be sought within the cupola itself, and in the application of the blower thereto, presumably along the lines in which improvement has already been made.

55 The air supply to a cupola is usually expressed in cubic feet per net ton of iron melted. The amount necessarily varies with the melting ratio, the density of the charges, and the incidental leakage. Fair average practice is represented by the following:

6 pounds iron per pound coke, 33 000 cubic feet of air per ton of iron
7 pounds iron per pound coke, 31 000 cubic feet of air per ton of iron
8 pounds iron per pound coke, 29 000 cubic feet of air per ton of iron
9 pounds iron per pound coke, 27 000 cubic feet of air per ton of iron
10 pounds iron per pound coke, 25 000 cubic feet of air per ton of iron

It is customary to provide blower capacity on a basis of 30 000 cubic feet, which corresponds to 75 or 80 per cent of the chemical requirements with average coke, and a melting ratio of 7.5 to 1. This is evidently ample for any higher ratio.

56 Obviously, neither the rate of combustion, nor the rate of melting, can remain constant under the varying conditions within the cupola. In fact it is not fundamentally necessary that they should. But the blower is usually run at constant speed, and delivers uniform volume except as reduced by resistance.

57 As a rule this reduction, which occurs only in the case of the fan, is relatively slight, for the volume (of which the velocity is a function) varies as the square root of the pressure. Hence, for instance, a 20 per cent drop in pressure entails only about 10 per cent loss in volume. Fairly constant pressure with a more regular, though not uniform volume, is therefore to be expected in fan blower cupola practice, as well as a moderate melting rate due to delayed combustion, resulting from reduction in air supply coincident with increase in resistance.

58 As ordinarily installed the resistance of a cupola will never exceed the pressure which a rotary blower can create if sufficient power is supplied. If no relief valve is provided, or it is set high enough to prevent escape, all air must be discharged through the cupola, hence the volume will be practically constant. As the pressure equals the resistance, considerable variation is to be expected

during the heat, while, owing to the maintenance of uniform air supply, a more rapid rate of melting may be possible than with the fan.

59 These expectations are usually fulfilled in practice, although the contrast lessens as the proportioning of the blower to the cupola approaches the ideal. So far as the blower is concerned, its actual volumetric output, relatively to the cupola requirements, is the determining factor in the melting rate. Fundamentally, the resistance regulates the volume in the case of the fan, while the volume regulates the resistance in the case of the rotary blower. Otherwise expressed, the fan type adjusts itself to the conditions, decreases the power and volume, and somewhat reduces the melting rate, while the rotary type in a resistless way continues to force through the cupola the prescribed volume regardless of immediate requirements or power expenditure, and usually maintains the maximum hourly output.

60 For the purpose of illustration, extreme contrasts between the operation of a fan blower and a rotary blower are graphically presented in Fig. 7. These curves are based on tests reported by Mr. H. E. Field at the December 1904 meeting of the Pittsburg Foundrymen's Association. The blowers, a No. 10 Sturtevant fan and a 33 cubic foot Connersville rotary, were installed for alternate use in connection with a 54 inch lining cupola. So far as possible the charges were alike in weight and character in both cases. The scrap was heavy, and of such shape as to pack closely. These tests will be made the basis for some pertinent comparisons.

61 Here are practically identical conditions of cupola and contents, but great contrasts in operation which show the effect of variation in air volume and pressure. With the fan blower the pressure was comparatively constant, the variation being between 12½ and 14⅛ ounces in the wind box with an average of 13.6. The net power ranged from 25 to 38.5 horse power, with an average of 31.2. The pressure with the rotary blower varied through the extreme range between 10½ and 25 ounces, while the average stood at 20.63. The variation in horse power was between 19 and 45, the average being 35.8.

62 With the fan 28.84 tons were melted in 3.77 hours, at the rate of 7.65 tons per hour, while with the rotary blower 2.82 hours were required to melt 31.5 tons, at an hourly rate of 10.6 tons, an increase of nearly 40 per cent in output. This reduces to a net input of 4.09 horse power per ton melted per hour with the fan, and 2.98 horse power with the rotary blower; an apparent advantage of 27 per cent in favor of the rotary.

63 By far the larger quantity of air was discharged by the rotary blower, the rate of melting being closely proportional to the volume as may be shown by a careful analysis of the tests. The rate is low for the size of the cupola, extremely so in the case of the fan, and is in part at least the result of excessive resistance presented by large pieces of scrap.

64 The results shown by these tests emphasize the possible effect of changes in the relation of the blowers to the cupola. Had the rotary blower been of smaller capacity such excessive pressures would

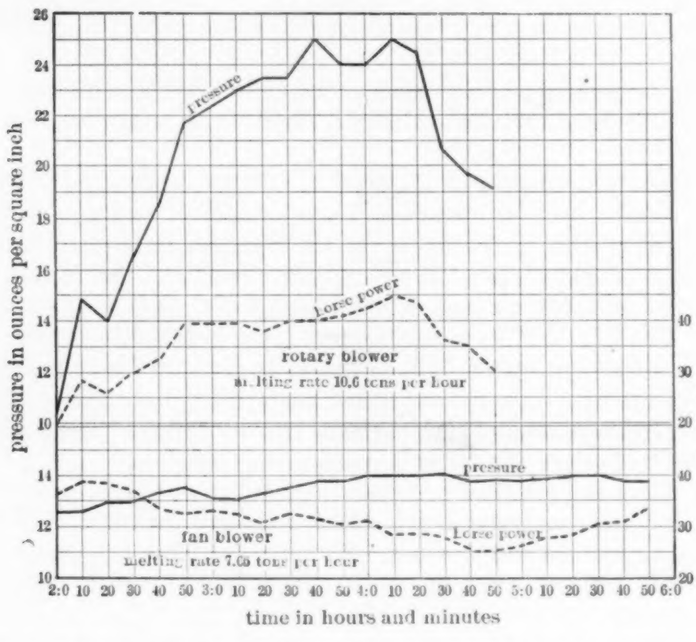

FIG. 7 PERFORMANCE OF FAN AND ROTARY BLOWER ON A 54 INCH CUPOLA

not have been necessary to force the constant volume through the cupola; the power would have been decreased, and the duration of the heat prolonged, with probable decrease in the horse power hours per ton. Had the fan been run at higher, but not excessive, speed, to permit of passing a larger volume, which it was fully capable of delivering, the horse power would have increased, the time decreased and the power per ton per hour would certainly have more closely approached that required by the rotary blower.

65 A subsequent unofficial, but credible, test made upon the same cupola equipped with a No. 8 Sturtevant fan presents an instruc-

tive contrast. The conditions were identical with those in the previous tests, except that a small amount of very light scrap was charged. The results showed 9.41 tons melted per hour, with an average pressure of 12.5 ounces and a power expenditure per ton per hour less than 80 per cent of that required with the No. 10 fan.

66 The preceding renders manifest the difficulties in the way of exactly proportioning blowers to the somewhat unknown conditions of their work, and likewise the futility of attempting to base comparisons of ultimate efficiency upon such limited experiments. In contrast thereto, it can be shown that a No. 10 Sturtevant fan, upon a 60 inch cupola, regularly melted 13.8 tons per hour, with an expenditure of 2.6 horse power per ton, and a No. 8, upon a 42½ inch, required only 2.9 horse power per ton upon a total output of 6.46 tons per hour. And likewise that rotary blowers of identical size and quality have shown results both inferior and superior to those here reported.

67 The higher speed of melting, which because of its ability to overcome excessive resistances, may be maintained by the rotary blower, is universally recognized, as is also the increased time thus rendered available for molding before the first iron is tapped. But the greater pressure incident to the higher rate is much more severe in its cutting effect upon the lining, while the value of the time gained for molding depends upon individual foundry conditions. The superior mechanical efficiency of the rotary type is, to a greater or less degree, offset by much lower first cost and fixed charges on the fan. The necessity of providing power capacity greatly in excess of the average in the case of the rotary blower is not to be overlooked. Neither is it to be forgotten that the brief duration of the heat reduces the difference in annual expenditure for power to a relatively unimportant item. For instance, under the exceptional conditions in the tests shown in Fig. 7, the daily difference in electrical horse power hours input was only 20.3. On a basis of 10 hours per day this equals only 2 horse power continuously exerted.

68 Theoretically, for otherwise constant conditions, the following relations hold for cupolas and melting rates within the range of practical operation;

a The melting rate with constant volume varies directly as the square of the diameter, that is, as the cross sectional area of the cupola, and directly as the volume, as the square root of the pressure, and as the cube root of the power for a given cupola.

b The volume varies inversely as the square of the cupola diameter for a given melting rate, and directly as the melting rate for any cupola.

c The pressure with a given cupola varies directly as the square of the volume, that is, as the square of the melting rate, and as the depth of the charges for a given melting rate.

d The power with a given cupola varies directly as the cube of the melting rate, and as the cube of the square root of the pressure, and directly as the pressure for a given melting rate and any cupola, i. e., inversely as the fourth power of the diameter for a given melting rate.

e The power per ton per hour (the operating efficiency) for a given cupola varies directly as the square of the melting rate, that is, as the pressure; and for a given melting rate directly as the rate for a given pressure, directly as the pressure and inversely as the fourth power of the diameter.

f The duration of the heat for a total output for a given cupola varies inversely as the square root of the pressure.

69 These relations might well be the source of numerous formulae for practical use were it possible to establish accurate coefficients. But the great variety in cupolas, twyerage proportions, and character of fuel and iron, to say nothing of the difference in charging practice in different foundries, or even the variety in the same foundry, bewildering and discouraging. Maximum efficiency in a given case can only be assured after direct experiment. But something short of the maximum is usually accepted in ignorance of the ultimate possibilities. But even though subject to some variation under working conditions, the preceding relations point clearly to the factors that make for maximum efficiency. It is obvious that pressure and melting rates should be as low, and cupola diameters as great as practical considerations will allow.

70 High pressure is a relic of small twyer area, in a single course, of coal as fuel, of false economy in buying a fan blower so small as to require excessive speed to deliver the required volume, or a rotary blower so proportioned to the cupola that high pressure is inevitable, and above all, of forcing the cupola beyond the economical limit. It is no longer considered creditable to secure the largest possible output from a given cupola; it is better practice to use a larger cupola for the same output. The tendency is distinctly in the line of more moderation, both because of higher ultimate operating efficiency, and the improved quality of the castings.

71 Figs. 8 and 9 clearly indicate the economy of such a course. It is to be noted that although the curve of maximum output in

Fig. 8 is freely drawn through points representing good current practice, it conforms closely to the relations expressed above, i. e., that the melting rate varies directly as the square of the diameter. Wide variations are to be expected in individual cases. The maximum pressures capable of maintaining the corresponding melting rates under proper conditions vary with the diameter and the height of the cupola, as well as with the proportions of the charges. Other melting rates are plotted in proportion to the square roots of lesser

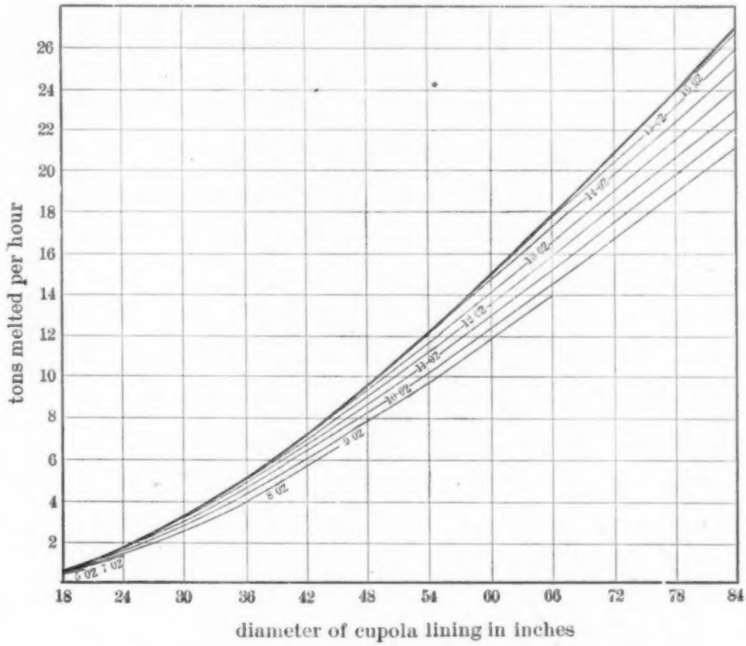

FIG. 8 CUPOLA PERFORMANCE AT DIFFERENT PRESSURES

pressures for corresponding cupola diameters. It is, however, because of the great variety in conditions that the values indicated by this or any other set of curves are purely relative and cannot be made directly applicable to cupola practice in general.

72 The power economy of low pressures and melting rates is clearly shown by Fig. 9. The lines of unit expenditure have been arbitrarily fixed in the middle field of good practice.

73 The actual melting range of a cupola is ordinarily between 0.6 and 0.75 ton per hour per square foot of cross section. The limits of air supply per minute per square foot are roughly 2500 and

4000 cubic feet, with the mean as representative of fair practice. The possible power required varies even more widely, ranging from 1.5 to 3.75 horse power per square foot, corresponding respectively to 2.5 and 5 horse power per ton per hour for the melting rates specified above.

74 Current practice can only be expressed between limits as in the case of Table 3. Therein is given the ordinary range of the different variables for stated cupola diameters. The specified pres-

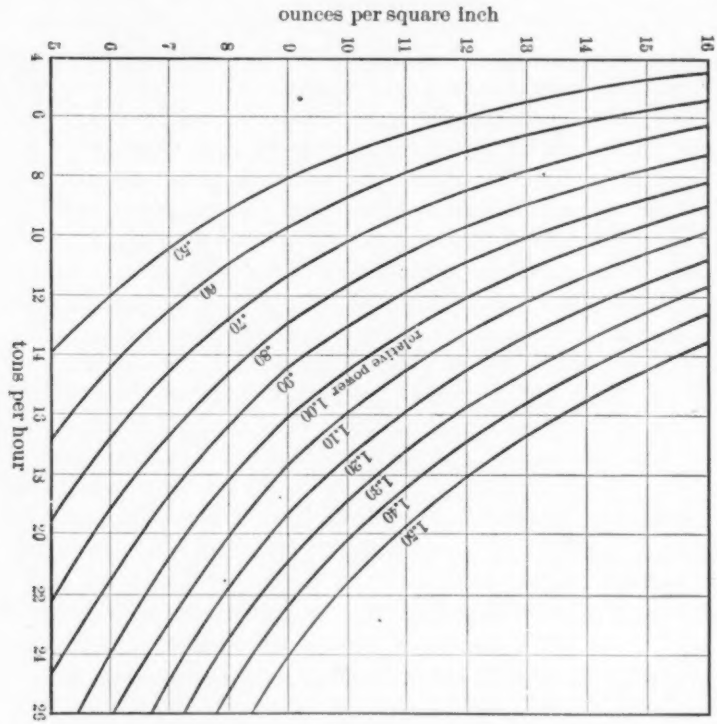

FIG. 9 ROTATIVE POWER FOR DIFFERENT PRESSURES AND MELTING RATES

sures prevail most extensively in recent installations. In so far as it is possible to determine the melting rate and the necessary pressure therefor, the power may be roughly calculated, from the theoretical requirement of 0.27 horse power to deliver 1000 cubic feet per minute against one ounce pressure. The power increases directly with the pressure, and is practically dependent upon the efficiency of the blower. This will range from 50 to nearly 70 per cent in a good fan installation, and up to a possible maximum of 90 per cent

with a first class rotary blower equipment. The drop in pressure due to an extended system of piping must not be neglected in such calculations.

75 The trend toward lower pressures in the cupola is reflected in current air furnace practice. The high pressure fan blower with small volumetric capacity has been superseded by the volume fan having ample capacity at much lower pressure.

76 Both volume and pressure are dependent upon the quality of the coal and the rate of combustion. The deep fire lends itself to complete utilization of the air supply, with minimum excess and maximum temperature. Both under and over grate supply pipes should be of ample size to avoid excessive loss by friction, and the

TABLE 3

RANGE OF PERFORMANCE OF CUPOLA BLOWERS

DIAMETER INSIDE LINING. IN.	CAPACITY PER HOUR TONS	PRESSURE PER SQ. IN. OZ	VOLUME OF AIR PER MIN. CU. FT.	HORSE POWER
18	0.25– 0.5	5– 7	150– 300	0.5– 1.5
24	1.00– 1.5	7– 9	600– 900	2.0– 6.0
30	2.00– 3.5	8–11	1 200– 2 000	5.0– 15.0
36	4.00– 5.0	8–12	2 200– 2 800	10.0– 23.0
42	5.00– 7.0	8–13	2 700– 3 700	12.0– 32.0
48	8.00–10.0	8–13	4 000– 5 000	18.0– 45.0
54	9.00–12.0	9–14	4 500– 6 000	22.0– 60.0
60	12.00–15.0	9–14	6 000– 7 500	30.0– 75.0
66	14.00–18.0	9–15	7 000– 9 000	35.0– 90.0
72	17.00–21.0	10–15	8 500–10 500	45.0–110.0
78	19.00–24.0	10–16	9 500–12 000	52.0–130.0
84	21.00–27.0	10–16	10 500–13 500	60.0–150.0

pressure should be the lowest which, with a properly proportioned blower, will pass the required volume. This pressure need not exceed 2½ ounces per square inch, and under good conditions should be considerably less. The volume delivered beneath the fire may be kept well down toward the theoretical requirements, not exceeding 200 to 225 cubic feet per pound of coal.

77 In the crucible furnace still lower pressures prevail but the air supply is not as effectively utilized.

78 Flexibility in the application and operation of a blower is sufficient to permit of approximation in its size. Unfortunately its size number conveys no idea of its capacity, although rotary blowers are secondarily classified by volumetric displacement. The manufacturer's recommendation, checked by the purchaser's experience, must generally serve as the simplest rule of selection.

DISCUSSION

COLLEGE AND APPRENTICE TRAINING

By Prof. John Price Jackson, Published in October Proceedings

Mr. Magnus W. Alexander Annually the technical colleges of the United States graduate thousands of young men into the industrial field, equipped with the theories of their professions, lacking practical experience, except for the small amount that the college laboratories afford, and generally unable to apply the theories accurately and effectively to the practical problems of the engineering business.

2 In order to adjust this equipment of the college graduate to the industrial requirements, large concerns and especially manufacturers of electrical apparatus, on account of the variety of their apparatus and the rapid development in their designs, have established "student courses," through which graduates must pass before joining the engineering staff of the company. The course usually lasts two years and prepares for positions as designing and estimating engineers, construction and commercial engineers and technical salesmen.

3 The majority of technical graduates embrace this opportunity for laying a broad foundation for a future career and apply themselves earnestly to the work. Some show a disinclination to enter a student course and advance various reasons for their attitude. Unwillingness to work long factory hours for a comparatively small compensation is one of these reasons, which, however, deserves no further consideration; necessity for the immediate earning of a larger income for financial reasons of one kind or another is a more plausible argument; the belief that the college laboratory and shop practice courses eliminate the need of further instruction concerning the handling and testing of machinery is sometimes encountered and indicates a wrong attitude toward and a misapprehension of the objects of a student course. Many times, while admitting the advantages of a training through a student course, the young man contends that much of the two years spent in this way is wasted; a criticism which finds justification in the fact that some student courses are conducted without effective direction, and lack system except in name,

thus reducing the course to a time-serving period. No doubt a well conceived and well conducted student course is the best means of initiating the junior engineer into his profession. The system prevailing at the Lynn Works of the General Electric Company is a concrete example of recognized efficiency, and a brief description of it may prove suggestive and may assist in the intelligent consideration of this important and interesting problem.

4 The General Electric Company at Lynn, Mass., manufactures a large variety of electrical apparatus besides steam turbines, centrifugal air compressors and other mechanical devices. The designing of this apparatus and its constant improvement, the supervision of its manufacture and erection, the development of new designs and new applications of the forces of nature, and last but not least the selling of the product of the factory call for a constant supply of engineering talent and service of a high order. The student course of the company is designed to meet this demand; it admits graduates of technical colleges and trains them during a period of two years. The object of this course is to give practical experience in handling and testing General Electric apparatus; to fix in the student's mind thoroughly the practical applications of the theory he has acquired at college; to enlarge his engineering knowledge; to offer an opportunity for becoming acquainted with efficiencies and characteristics of General Electric machinery and their competitive value by contrasting them with the product of other manufacturers; and generally to develop the young man along the lines of his future usefulness to the company.

5 In order that this plan may be carried out effectively with due consideration for each individual student, a Supervisory Committee was organized about two years ago, consisting of the superintendent of testing rooms, who is in general charge of the student course, and three engineers representing different departments of the works. The committee meets either weekly or fortnightly as conditions may require. Each new student appears before the committee sometime during the first three months of his service, merely to be introduced to the members, who question him as to his future intentions and advise him as to the best way to accomplish the desired end. The committee makes a note of its general impression of the student, who is called again in about six months, when he is examined quite fully with regard to his theoretical and applied technical knowledge, his alertness in taking advantage of the educational opportunities offered by the course, and his general make-up. This examination is repeated usually at intervals of six months, though sometimes

oftener, especially in cases when, on account of a previous unsatisfactory examination, the student has been placed on probation.

6 The examinations are conducted by the individual members of the committee not with any desire to pick flaws in the educational armor of the young man, but rather with the aim of assisting him in his work and pointing out to him the way to success. The committee assumes quite frequently the rôle of a prospective customer: "I have decided to install arc lamps in my factory and have about made up my mind to award the contract to the X Y Co. What have you to say to this?" may be a question put to a student who has already had experience in the arc lamp department and intends to become a salesman of the company. The way in which he answers will give the committee a cue as to his general character and his probable success as a salesman.

7 One student will present that ambiguous smile that indicates his helplessness in meeting the situation, if not his ignorance; another, in boy-like fashion, will blurt out with his advice that the prospective customer should buy from the General Electric Company, and will then rest, entirely satisfied with his answer; while another, after a moment of reflection will endeavor, through argument, to convince the questioner of the advantages of the General Electric arc lamps over others. The committee feels that in this latter case they are dealing with an embryo-salesman who is now picked up on one or the other of his statements and, step by step, led to explain the theories that underlie the operation of an arc lamp and govern its light distribution. The prospective engineer, on the other hand, may be confronted with an inquiry as to the most desirable motor, electrically and mechanically, for driving a large planer in a machine shop. A quick reply is not expected of him; a few minutes of reflection and then an answer based on scientific argument is looked for by the committee. This question with its accompanying answer gives the committee a splendid opportunity for testing the student's electrical knowledge in many directions, and for discovering his mechanical engineering ability. The committee, however, does not rest satisfied with a discussion of the appropriate General Electric motor for this particular purpose, but endeavors to find out from the student its competitive value with motors of other manufacturers. A reply confessing ignorance as to the characteristics of other motors is allowed to pass only at the first examination without censure. At that time it is pointed out to the student that the reading of the advertising pages of technical magazines and a study of the pictures contained therein will furnish a great deal of information of the work

of competing manufacturers from whom, furthermore, descriptive catalogues can be obtained by those who really want them; the importance of keeping alert in obtaining such information is impressed upon the students.

8 Thus each student is treated individually before the committee and is given just that kind of advice that will be of the greatest benefit to him; the correct sizing up of the young man at his first appearance before the committee is, therefore, of great importance. After each examination the members of the committee immediately compare their judgments and acquaint him with their estimate of him and their advice to him. The committee's opinion, which is not considered final unless unanimous, is recorded in the minutes and a card index of each student gives a running record of his development. Toward the end of the two years' course a final examination of each student takes place, after which the committee endeavors to find a suitable position for him.

9 The practical ork of the factory, while directly under the charge of the superintendent of testing rooms, is naturally influenced by the work of the committee. Each student is transferred from one department to another, not according to an iron-clad schedule of time, but according to his efficiency in any one part of his work. Every student is stimulated to get the right conception of his work day by day, by obtaining light on any doubtful point that may arise in his mind. An exchange of ideas with his fellow students in the factory or in an evening's conversation, or the refreshing of his knowledge by consulting engineering books, may clear up his mind on doubtful points; moreover, the superintendent of testing rooms or his assistants, and the engineers of the company stand ready to assist with advice. Such systematic guidance in the practical work in the factory and the supplemental advice of the committee stimulate the student to correlate theory and practice day by day; to think logically and with a perspective of the real issue involved; and to make the most effective use of his two years' apprenticeship.

10 The committee contemplates a further extension of its usefulness. Although it is satisfied that every student, having received his diploma from his college, has acquired engineering knowledge, it has frequently been appalled by the utter inability of some students to perceive the right relation between theory and practice, and to reason from effect to cause, though at the same time they are capable of reasoning from cause to effect. It is the intention, therefore, to call together all students, in groups of about ten, for one hour per week, when just such questions as are now put to them in an exam-

ination before the committee will be brought up in relation to the successive steps of the practical work in the factory. It will not be a weekly examination, neither will it be a weekly lecture; it might perhaps be called a "seminar" in which the members of the committee and the students may exchange in an informal way practical engineering ideas according to a preconceived program. I feel sure that such effort will be productive of excellent results and will develop a body of young men well trained, both in the practice and theory of the engineering profession, alert, efficient, and, no doubt, imbued with a spirit of loyalty to the company. What more valuable asset could a company boast of than a staff of engineers recruited from the best elements of such a student body?

Dr. H. S. Pritchett Professor Jackson's paper touches, as it seems to me, a most vital question in our industrial and educational work. We all recognize that the education of the high-grade engineer in this country has been well looked after. We recognize with equal clearness that the education of the foreman and the mechanic has been practically neglected. The work which Professor Jackson describes is intended to be a link between the technical colleges and the industries and to serve the needs of the class of men to whom I have just referred. It is an interesting spectacle in educational development that this problem should be undertaken by manufacturers and that, up to this time, they have shown more interest in the matter than have the school men. Those who remember the beginnings of engineering education in this country realize that in the movement for higher engineering education, which took place some forty or fifty years ago, it was the school men who moved first and a long time elapsed before they were able to obtain from those who employed engineers much recognition.

2 I venture to make this single suggestion. All of us realize the pressing necessity for some solution of the problem of industrial training. If America is to hold its own in the world, its citizens must be trained to become effective economic units. That end will, in my judgment, be gained only by coöperation on the part of those who teach and of those who employ the young apprentice and the solution of the problem will be possible only by securing at the same time the coöperation and good will of those who are to be taught.

Prof. C. F. Park Four years ago, a new free evening school was opened in Boston. This school was a substitute of the Lowell Institute for its advanced lecture courses which had been given for more than thirty years by professors of the Institute of Technology.

2 Among the different classes in the community there appeared to be one which had hardly received the attention it deserved. It was for this class, the foremen, that the school was planned. These men receive the same education today as the ordinary mechanic, and it was thought that it would be a great benefit to the community at large if they could have some training in the principles of applied science. The difficulty of finding men who can occupy positions of responsibility as foremen is realized by all who are connected with the management of mechanical industries.

3 To attempt however to train young men separately for the position of foremen would be, under the existing organization of labor, an impossibility, as the foremen must continue for the present, at least, to be promoted from among the workmen. Therefore, to give them such an education as is desired, it is necessary to train men who are already working at their trade. With this object the "School for Industrial Foremen" of the Lowell Institute under the auspices of the Massachusetts Institute of Technology was started and is yielding very satisfactory results.

4 The school comprises two courses, one mechanical and the other electrical, and each extending over two years. These courses are intended to bring the systematic study of applied science within the reach of men who are following industrial pursuits and desire to fit themselves for higher positions, but are unable to attend courses during the day.

5 The subjects in the first year for both courses are: Practical Mathematics (including Calculus); Elementary Physics and Electricity; Elements of Mechanism; and Drawing.

6 The subjects in the second year Mechanical course are: Mechanics; Valve-Gears; Elements of Thermodynamics, the Steam Engine and Boilers; Elementary Hydraulics; Testing Laboratory (Resistance of Materials); Steam and Hydraulic Laboratory; and Mechanism Design and Elementary Machine Design.

7 The second year Electrical course includes: Valve-Gears; Elements of Thermodymanics, the Steam Engine and Boilers; Steam Laboratory; Direct Current Machinery; Alternating Currents; Electric Distribution; Electrical Testing (Laboratory); and Laboratory of Dynamo Electric Machinery.

8 It has been the aim to adapt the courses to the needs of the men for whom the instruction is intended and to include the study of those principles with which they are not likely to become familiar in practice, and which will give them a fundamental training in those matters that will be of the greatest value to them in the work in which they are regularly engaged.

9 The school is open to those only who are ambitious and willing to study. The character and amount of the instruction is such that attendance is required for three or four evenings a week, and men who cannot also devote considerable time to study away from the school cannot derive full benefit from the instruction, nor perhaps maintain their standing.

10 To be admitted to the courses the applicant must be at least eighteen years of age, and must pass entrance examinations in Arithmetic, including the Metric System; Elementary Algebra; Plane Geometry; and Mechanical Drawing. In addition to the examinations considerable weight is attached to the applicant's occupation and practical experience.

11 The instruction embraces recitations, lectures, drawing-room practice, and laboratory exercises; and is given by members of the instructing staff of the Institute of Technology. The success of the instruction is due in part to the fact that it is specially adapted to the needs of the men and is making them more efficient in their regular occupations and qualifying them for advancement along the lines in which they are working. Text-books are used in many of the subjects, but in some of the work, where the instruction differs widely from available books, printed notes are supplied to the students at cost. Many of the lectures are fully illustrated by apparatus and experiments. Written tests are given from time to time, and problems are assigned for home work at nearly every exercise.

12 The courses are undoubtedly severe, and there are probably not a large number of men who are able to carry them. The scholarship of the students and their ability to continue the courses is determined in part by examinations, but considerable weight is given to the term's work. Those who fail to keep well up with the work or to profit sufficiently by the instruction are disqualified to continue the course. Those who complete satisfactorily the required courses and pass the examinations are given certificates.

13 It may be supposed that men who are following industrial pursuits during the day are not in a condition to receive instruction after their day's labor, and that instruction under such conditions can be of but little profit; but it can be safely stated that for the four years of the school's history the men have spent two hours at the school three or four evenings a week and as many more hours at home in study for a school-year of thirty weeks and have achieved thorough efficiency in their studies.

14 The shrinkage in attendance has been comparatively small. About as many men have been able to keep up with the standard of

scholarship as it had been thought wise to teach in one section in the work of the second year. The size of the first-year class has been about 70, and that of the second-year class about 50. Ninety men have been graduated in three classes—about 30 in each class.

15 A great variety of occupations are represented in the school, but usually a few more than half the number of students are draftsmen or machinists. The men have come from about thirty different companies or corporations in the city or the vicinity. Their average age has been about 27 years and nearly all of them have attended high school or have passed through that grade.

16 The occupations of the men in the first class of the school were as follows:

Blacksmith's helper	1
Car repair man	1
Civil engineer	1
Clerk	6
Draughtsmen	24
Electrical engineer	1
Electrician	2
Electric railway construction	1
Engineer	3
Engineer of construction	1
Inspector, switchboard, wire, meter	3
Instrument-maker	2
Laboratory assistant	2
Linemen or instrument men	2
Locomotive firemen	1
Machinist	14
Manager Municipal Light Plant	1
Meter testing or installing meters	2
Ordnance man	1
Pattern-maker	1
Station agent	1
Telephone engineer	1
Tool-maker	1
Miscellaneous	5
	78

17 These men have attended the exercises of the school regularly; have taken deep interest in the instruction, and have made untiring effort to do the work. This has continued to the end of the course; and, considering the circumstances under which they have worked, the results have been surprising as well as very gratifying.

18 Much attention is being given throughout the country to the training of the technical engineer, but little, if any, to the training

of the foreman or the mechanic, and almost nothing is being done to fill in that gap which lies between the trained engineer on the one hand and the partially trained workman on the other. The country is well supplied with technical schools of college rank which are turning out technical engineers; but there is great need of a technical school, of high grade, whose function shall be to train foremen and superintendents, or to fit men to occupy such positions. We have heard a great deal of late years of captains of industry; but the efficiency of the industrial art depends, in a very large measure, and probably to a constantly increasing extent, upon the capacity of its non-commissioned officers, in other words, upon the foremen.

19 President Wilson has said that "Colleges are not planned for the majority; they are for the minority." So this school for foremen is not planned for the great mass of working people but for the minority of that class who are not uneducated but who have been unable to gain a technical education; that class which has the ability and the enthusiasm to embrace the opportunity to gain training in applied science in the evening at the same time that they are following regular occupations through the day time.

20 It was felt when the school was planned that it would be more valuable both to the men themselves and to the industrial community to give this training of high standard to a comparatively small number of men rather than to give training of a lower grade to a large number of men. That there is a demand for this kind of instruction has been demonstrated by our experience. It was felt, also, that a better educated class of foremen would be a benefit to the community socially, as an intermediary class between the employer or engineer, on the one hand, and the workmen, on the other.

21 Such schools as this free evening school of the Lowell Institute would enable men who are earnest and capable, and who are unable to attend regular day classes, the opportunity to pursue a systematic study of applied science during the evening, at the same time that they are working through the day, and to receive training of high grade in the same subjects that are presented in a high grade Mechanical or Electrical Course: training that will aid them to make more rapid progress and to advance to a higher point than would otherwise have been possible. Training of this kind will not only bring more enjoyment and a higher salary to the man, but it will put his whole life and that of his family on a higher plane than it would otherwise have been. Such men are needed in our mechanical industries.

MR. G. M. BASFORD It is not pleasant to sound a discordant note in the discussion of a paper so carefully and thoughtfully prepared, but, speaking from the standpoint of one who has worried about this question in an organization of 21 000 men, it seems vitally necessary to point out an error which is now serious and will certainly become more serious. It is well to provide for college men in industrial organizations but the experience of the past thirty years has proved and present experience is proving every day that the vital need lies not in college men but in the shop workmen upon whom we depend for output and for those things which may be summed up in one word—"results." It is well to provide for the college men; it is, however, a mistake more serious than most of us can now realize to provide for them unless we have previously put our shop recruiting system for the workmen—the men who do our work—upon a proper basis. I cannot find the words to say, as it ought to be said, that college graduate apprenticeship is wrong from every standpoint unless based upon and preceded by a proper recruiting system and what we generally understand by the term, "regular apprenticeship."

2 If we have a proper regular apprenticeship system we have a moral right to deal with college graduate apprenticeship. If we have not such a system, we have no such right and we are making an error for which we shall in time pay dearly. It is easy to realize that this is not a popular sentiment to express, but a warning is evidently needed lest we build our pyramid upon its apex. We stand in need of captains and a few subordinate officers, but we stand in greater need of an intelligent rank and file. In developing the first class let us not kill the second. If we had a good organization as to the rank and file, the captains and subordinate officers would not constitute a problem. It is from the rank and file that we always have and always will develop leaders. We shall suffer in the long run for any policy which tends in any way to discourage ambition in the large class of men upon whom we must rely. The best we can do for an industrial organization and for everyone who enters it is to put recruits upon an actual rather than an artificial footing, allowing everyone to make his place in the organization in competition with everybody else. The company already alluded to has for two years made a practice of taking college men in as workmen at a living wage with no promises and no special privileges. The plan is working well and promises well.

MR. C. W. CROSS With special reference to the college man as an apprentice in a manufacturing establishment or a railroad shop, the

author wishes to say, after a number of years experience in shop work, he has the very highest respect and greatest possible admiration for the young man who, without the spur of necessity, has the pluck to go into the actual work of the shop after graduation from a technical school. This practice is by no means common, but the notable instances of men who have made a brilliant success of their career proves the wisdom of the plan of actual close contact with shop conditions as the only means of learning the business properly, and at the same time, of learning the most important feature, the handling of men, which can be learned only in this manner.

2 There are many instances however, where the young man makes the serious mistake of presuming that the possession of his diploma takes the place of energy and effort, and marks him as a superior person and all he has to do is to "play around the edges" of the business for a short time and then reap the reward of his superiority as indicated by the possession of the diploma. But usually the young man is disappointed and instead of rapid advancement, he finds that other young men, who have not had the educational advantages he has enjoyed, are being promoted around him and outstripping him in every respect. Numerous instances of this kind prove that a young man cannot be prepared for actual responsibility except by an apprenticeship that enables him to learn the details of the business in a manner that will make him a genuine product and a part of the business.

3 There are no text books on "horse sense." This can only be learned by experience and contact with others. Rare instances of the short cuts achieved by some man described as a "genius" are so infrequent that they cannot be depended upon as a plan to be followed by the great majority.

4 In our opinion the right manner for a college graduate to properly learn the business in a railroad shop is to enter the shop as a regular apprentice, with an understanding that he will be given credit, in time and pay, on his apprenticeship on account of previous experience in school shops, or the equivalent. This practice is the only one to give the young men the kind of training needed for their success and advancement.

5 The reason why many college men fail in railroad service, is that they have not had the right kind of training as a supplement to their education.

6 We believe it is unwise to use the term "special apprentice" as referring to a college graduate who goes into a business for a short special training for promotion. This practice is a handicap to the

college men by engendering class hatred and it unfair to the large number of worthy and competent young men who are on the list as regular apprentices. The best trained minds backed by the proper practical training will realize the advancement merited.

Mr. W. B. Russell Why is the technical graduate so useless? Because he has spent four of the most receptive years of his life out of touch with actual shop and labor conditions, and out of touch with practical commercial life and ideas of cost, economy and output.

2 Special apprenticeship is successful only in electrical works and even there it does not touch the actual shop or manufacturing end of the business. One of the best systems in the country turns only 7 per cent of its product into the "works." The vast majority of manufactories in the United States are on lines of work which make it impossible to create an atmosphere suited to student apprenticeship.

3 The two most serious needs in our present industrial condition are, *a* The need for skilled mechanics; *b* the need for industrial leaders who can understand men; can organize their efforts and can cut out lost motion to the mutual advantage of both employer and employee. The first need can be met by a proper system of regular apprenticeship. The second need can be met by the technical school, but in order to do this, two more or less radical changes, must be instituted. The special apprenticeship, or better still, regular apprenticeship, and the technical course should be carried on at the same time instead of one following the other, and the present courses in mechanical engineering should be simplified and thereby strengthened and made more effective.

4 In regard to the first requisite, many colleges are already requiring shop work during vacations. The University of Cincinnati is trying with success the method of alternate weeks in school and shop. Any method will be satisfactory that gives the boy an intimate knowledge of shop and labor conditions during the receptive period of his life.

5 Referring to our technical courses, the author takes issue with Professor Jackson's opinion that present courses should be lengthened. It is true, as stated in Par. 37, that "the industrial complexity of life is multiplying rapidly," but it is also true, as stated in Par. 38 that "the university must confine itself to a large extent to the teaching of the fundamental truths of nature." To judge by the steady cramming of courses and raising of entrance requirements, the fundamental truths of nature are increasing at a terrific pace.

6 It is impossible for technical courses to cover all the varied applications of science and the attempt to do this is demoralizing. Manufacturers do not want men who know it all, but men who in this "industrial complexity" can get back to fundamentals; men who can think and who can tackle new problems. This type of man is better produced by a thorough training in a few subjects than by an increase in the number and grade of subjects taught. It is the story of the arithmetic. Each author made his book a little larger than that of his predecessor. The difference lies here; the writers of the arithmetics have seen their error; short practical books are again on the market.

7 This criticism is friendly; the author graduated from what he considers the best technical school in the world, and he wants this school to have a part in solving our present industrial problem, which is one of the most serious this country has ever faced.